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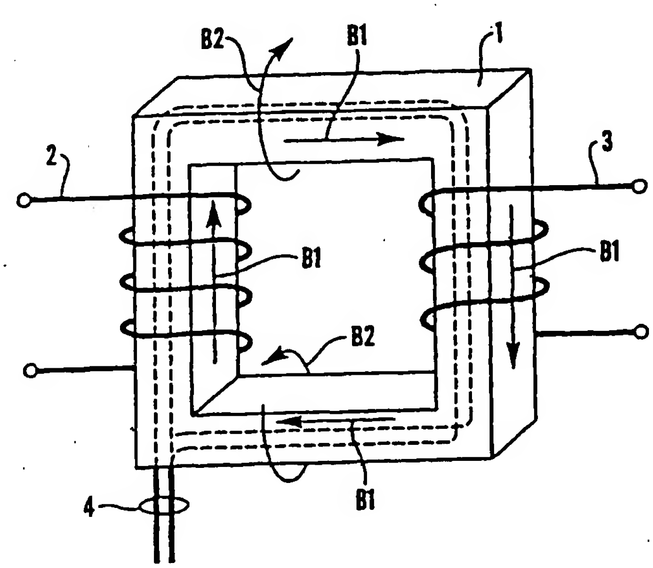

(57) Abstract: The invention relates to a magnetically influenced current or voltage regulator comprising a body (1) which is composed of a magnetisable material and provides a closed, magnetic circuit, at least one first electrical conductor (8) wound about the body of a first main winding (2) and at least one second electrical conductor (9) wound about the body of a second main winding (4). The winding axis (A2) for the main winding (2) is at right angles to the winding axis (A4) for the control winding (4) with the object of providing orthogonal magnetic fields (H1, B1 and H2, B2 respectively) in the body (1) and thereby controlling the behaviour of the magnetisable material relative to the field (H1, B1) in the main winding (2) by means of the field (H2, B2) in the control winding (4).

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MAGNETIC CONTROLLED CURRENT OR VOLTAGE REGULATOR AND TRANSFORMER

The present invention relates to a magnetically influenced current or voltage regulator and a magnetically influenced converter for controlled connection and disconnection together with distribution of electrical energy as indicated in the introduction to the attached, independent patent claims..

The invention, which is a continuation of the known transductor technology, is particularly suitable as a voltage connector, current regulator or voltage converter in several areas of the field of power electronics. The feature which particularly characterises the invention is that the transformative or inductive connection between the control winding and the main winding is approximately 0 and that the inductance in the main winding can be regulated through the current in the control winding, and furthermore that the magnetic connection between a primary winding and a secondary winding in a transformer configuration can be regulated through the current in the control winding.

In the field of rectification, for example, the present invention can be employed in connection with regulation of the high-voltage input in large rectifiers, where the advantage will be full exploitation of a diode rectifier over the entire voltage range. For asynchronous motors, the use of the invention may be envisaged in connection with the soft start of high-voltage motors. The invention is also suitable for use in the field of power distribution in connection with voltage regulation of power lines, and may be used for continuously controlled compensation of reactive power in the network.

Even though it should not be considered limiting for the use of the device, it may, e.g., form part of a frequency converter for converting input frequency to randomly selected output frequency, preferably intended for operation of an asynchronous motor, where the frequency converter's input side has a three-phase supply which by means of its phase conductors feeds the input to at least one transformer intended for each of the converter's three-phase outputs, and where the outputs of such a transformer are connected via respective, selectively controllable voltage connectors, or via additional

transformer-coupled voltage connectors, in order to form one of the said three-phase outputs.

A second application of the device is as a direct converter of DC voltage to AC voltage whereby the AC voltage's frequency is continuously adjustable.

The use of this type of frequency converter in a subsea context, especially at great depths, will be where the use is required of high-capacity pumps with variable speeds. Pumping in a subsea system will typically be performed from the underwater site to a location above water (boosting) and with water injection from the underwater site down into the reservoir.

Variable speed engine controls are normally based on two principles; a) direct electronic frequency-regulated converters, and b) AC-DC-AC converters with pulse-width modulation, and with extended use of semiconductors such as thyristors and IGBT's. The latter represents the technology widely used in industrial applications and for use on board locomotives, etc.

Speed control has recently been introduced for motors in underwater environments. The main challenge has been the packing and operation of such systems. In this context, operation refers to service, maintenance, etc. Complex electronic systems generally have to operate in controlled environments with regard to temperature and pressure. Marine-based versions of such systems have to be encapsulated in containers filled with nitrogen maintaining a pressure of 1 atm. On account of heat generation as a result of heat loss in the electronics, a substantial amount of heat may be generated, thus resulting in the need for forced air cooling. This is usually solved by the use of fans. The fans introduce a component which dramatically reduces the working life of the system and represents a highly unsuitable solution.

The sensitivity of the electronics and the electronic power semiconductors is high and requires protective circuits. This complicates the system and forces up the costs.

At great depths (over 300 metres) a protective container for such a system will be extremely heavy, representing a fairly significant proportion of the total weight of the system. In addition, maintenance of a system more often

than not will require the entire frequency converter to be raised, since even simpler maintenance is difficult to perform with a remotely operated vehicle (ROV).

Thus it has been a co-ordinate object of the device according to the present invention to offer the possibility of providing a frequency converter which is suitable for underwater pumping operations, particularly with the focus on operational reliability, stability and minimum maintenance requirements. The operational requirement will be approximately 25 years at 3000 m depth.

The standard frequency converters which are based on semiconductor technology convert alternating current (AC) power with a given frequency to alternating current power in the other selected frequency without any intermediate DC connection. The conversion is carried out by forming a connection between given input and output terminals during controlled time intervals. An output voltage wave with an output frequency F0 is generated by sequentially connecting selected segments of the voltage waves on the AC input source with the input frequency F1 to the terminals. Such frequency converters exist in the form of the standard symmetrical cycloconverter circuits for supplying power from a three-phase network to a three-phase motor. The standard cycloconverter module consists of a dual converter in each motor phase. Thus the normal method is to employ three identical, essentially independent dual converters which provide a three-phase output.

Amongst other known types of frequency converters is a symmetrical 12-pulse centre cycloconverter consisting of three identical 4-quadrant 12-pulse centre converters, with one for each output phase. All three converters share common secondary windings on the input transformer. The neutral conductor can be omitted for a balanced 3-phase loaded Y-coupled motor.

Another known frequency converter based on semiconductor technology is the so-called symmetrical 12-pulse bridge circuit which has three identical 4-quadrant 12-pulse bridge converters with one for each output phase. The input terminals on each of the six individual 6-pulse converters are fed from separate secondary windings on the input transformer. It should be noted that it is not permitted to use the same secondary winding for more than one converter. This is due to the fact that each 12-pulse converter in itself requires two completely insulated transformer secondary windings.

It has therefore been a secondary, but nevertheless essential object of the invention to avoid primarily semiconductor components in the frequency converter which has to be located at great depths and for this purpose the use has therefore been proposed according to the invention of the new magnetic converter technology based on an entirely untraditional concept.

Thus the invention comprises a magnetically influenced current or voltage regulator, which in a first embodiment is characterized in that it comprises: a body which is composed of a magnetisable material and provides a closed, magnetic circuit, at least one first electrical conductor wound round the body along at least a part of the closed circuit for at least one turn which forms a first main winding, at least one second electrical conductor wound around the body along at least a part of the closed circuit to at least one turn which forms a second main winding or control winding, where the winding axis for the turn or turns in the main winding is at right angles to the winding axis for the turn or turns in the control winding. The object of this is to provide orthogonal magnetic fields in the body and thereby control the behaviour of the magnetisable material relative to the field in the main winding by means of the field in the control winding. In a preferred version of this first embodiment, the axis for the turn(s) in the main winding is parallel to or coincident with the body's longitudinal direction, while the turn(s) in the control winding extend substantially along the magnetisable body and the axis for the control winding is therefore at right angles to the body's longitudinal direction. A second possible variant of the first embodiment consists in the axis for the turn(s) in the control winding being parallel to or coincident with the body's longitudinal direction, while the turn(s) in the main winding extend substantially along the magnetisable body and the axis for the main winding is therefore at right angles to the body's longitudinal direction.

This first embodiment of the device can be adapted for use as a transformer by being equipped with a third electrical conductor wound around the body along at least a part of the closed circuit for at least one turn, forming a third main winding, the winding axis for the turn or turns in the third main winding coinciding with or being parallel to the winding axis for the turn or turns in the first main winding, thus providing a transformer effect between the first and the third main windings when at least one of them is excited. A second possibility for adapting the first embodiment of the invention for use

as a transformer is to equip it with a third electrical conductor wound around the body along at least a part of the closed circuit for at least one turn, forming a third main winding, the winding axis for the turn or turns in the third main winding being coincident with or parallel to the winding axis for the turn or turns in the control winding, thus providing a transformer effect between the third main winding and the control winding when at least one of them is excited.

A second embodiment of the invention comprises a magnetically influenced current or voltage regulator, characterized in that it comprises a first body and a second body, each of which is composed of a magnetisable material which provides a closed, magnetic circuit, the said bodies being juxtaposed, at least one first electrical conductor wound along at least a part of the closed circuit for at least one turn which forms a first main winding, at least one second electrical conductor wound around at least a part of the first and/or second body for at least one turn which forms a second main winding or control winding, where the winding axis for the turn or turns in the main winding is at right angles to the winding axis for the turn or turns in the control winding. The object of this is to provide orthogonal magnetic fields in the body and thereby control the behaviour of the magnetisable material relative to the field in the main winding by means of the field in the control winding. The main and control windings may of course be interchanged, thus providing a magnetically influenced current or voltage regulator, characterized in that it comprises at least one first electrical conductor wound round at least a part of the first and/or the second body for at least one turn which forms a first main winding, at least one second electrical conductor wound along at least a part of the closed circuit for at least one turn which forms a second main winding or control winding, where the winding axis for the turn or turns in the main winding is at right angles to the winding axis for the turn or turns in the control winding with the object of providing orthogonal magnetic fields in the body and thereby controlling the behaviour of the magnetisable material relative to the field in the main winding by means of the field in the control winding.

A preferred variant of this second embodiment comprises first and second magnetic field connectors which together with the bodies form the closed magnetic circuit.

This second embodiment of the device can also be adapted for use as a transformer by equipping it with a third electrical conductor wound for one turn which forms a third main winding, the winding axis for the turn or turns in the third main winding being coincident with or parallel to the winding axis A2 for the turn or turns in the first main winding or in the control winding, thus providing a transformer effect between the third main winding and the first main winding or the control winding when at least one of this is excited.

In a preferred version of this second embodiment of the invention, the first and the second body are tubular, thus enabling the first conductor or the second conductor to extend through the first and the second body. In this version the magnetic field connectors preferably comprise apertures for the conductors. In a more preferred version of the invention, each magnetic field connector comprises a gap to facilitate the insertion of the first or the second conductor. In an even more preferred embodiment the device is equipped with an insulating film placed between the end surfaces of the tubes and the magnetic field connectors with the object of insulating the connecting surfaces from each other in order to prevent induced eddy currents from being produced in the connecting surfaces by short-circuiting of the layer of film. For a core made of ferrite or compressed powder, an insulation film will not be necessary. Furthermore, it is particularly advantageous that each tube in this second embodiment comprises two or more core parts and that in addition an insulating layer is provided between the core parts. The tubes in this second embodiment of the invention, moreover, may have circular, square, rectangular, triangular or hexagonal cross sections.

A third embodiment of the invention relates to a magnetically influenced current or voltage regulator, characterized in that it comprises a first, external tubular body and a second, internal tubular body, each of which is composed of a magnetisable material and provides a closed, magnetic circuit, the said bodies being concentric relative to each other and thus having a common axis, at least one first electrical conductor wound round the tubular bodies for at least one turn which forms a first main winding, at least one second electrical conductor provided in the space between the bodies and wound around the bodies' common axis for at least one turn which forms a second main winding or control winding, where the winding axis for the turn or turns in the main winding is at right angles to the winding axis for the turn or turns

in the control winding. The object again is to provide orthogonal magnetic fields in the bodies and thereby control the behaviour of the magnetisable material relative to the field in the main winding by means of the field in the control winding. The main winding and the control winding will also be interchangeable in this third embodiment of the invention, thus providing a magnetically influenced current or voltage regulator, where at least one first electrical conductor is provided in the space between the bodies and wound round the bodies' common axis for at least one turn which forms a first main winding, at least one second electrical conductor is wound around the tubular bodies for at least one turn which forms a second main winding or control winding, and the winding axis for the turn or turns in the main winding is at right angles to the winding axis for the turn or turns in the control winding.

A preferred variant of this third embodiment of the invention comprises first and second magnetic field connectors which together with the bodies form the closed magnetic circuit.

This third embodiment of the device can also be adapted for use as a transformer by equipping the device with a third electrical conductor wound for at least one turn which forms a third main winding. In this case too the winding axis for the turn or turns in the third main winding may either be coincident with or parallel to the winding axis for the turn or turns in the first main winding, thus providing a transformer effect between the first and the third main windings when at least one of this is excited, or the winding axis for the turn or turns in the third main winding may be coincident with or parallel to the winding axis for the turn or turns in the control winding, thus providing a transformer effect between the third main winding and the control winding when at least one of this is excited

A fourth embodiment of the invention relates to a magnetically influenced current or voltage regulator, characterized in that in the same manner as in the third embodiment of the invention it comprises a first, external tubular body and a second, internal tubular body, each of which is composed of a magnetisable material and forms a closed, magnetic circuit or internal core. The device also comprises an additional tubular body which provides an external core mounted on the outside of the first, external tubular body, where the bodies are concentric relative to each other and thus have a common axis, at least one first electrical conductor wound round the tubular

bodies for at least one turn which forms a first main winding, at least one second electrical conductor provided in the space between the first and the second body and wound around the bodies' common axis for at least one turn which forms a second main winding or control winding, where the winding axis for the turn or turns in the main winding is at right angles to the winding axis for the turn or turns in the control winding. The object again is to provide orthogonal magnetic fields in the body and thereby control the behaviour of the magnetisable material relative to the field in the main winding by means of the field in the control winding. In the same way as in the second embodiment of the invention, the main winding and the control winding may be interchangeable, thus providing a device where at least one first electrical conductor is provided in the space between the first and the second bodies and wound round the bodies' common axis for at least one turn which forms a second main winding or control winding, at least one second electrical conductor is wound around the tubular bodies for at least one turn which forms a second main winding or control winding.

A preferred variant of this fourth embodiment of the invention comprises first and second magnetic field connectors which together with the bodies form the closed magnetic circuit.

This fourth embodiment of the device can also be adapted for use as a transformer by equipping it with a third electrical conductor wound around the external core for one turn which forms a third main winding. In this case too there will be two alternatives: one where the winding axis for the turn or turns in the third main winding is coincident with or parallel to the winding axis for the turn or turns in the first main winding, thus providing a transformer effect between the first and the third main windings when at least one of this is excited, and one where the winding axis for the turn or turns in the third main winding is coincident with or parallel to the winding axis for the turn or turns in the control winding, thus providing a transformer effect between the third main winding and the control winding when at least one of this is excited.

It is, of course, possible to implement this fourth embodiment of the invention in such a manner that the two tubular bodies which form the internal core are mounted on the outside of the tubular body forming the

external core, thus providing an internal core with one tubular body and an external core with two tubular bodies.

In a preferred variant of this fourth embodiment of the invention, the device is characterized in that the external core consists of several annular parts, and that the first and/or the third main winding forms individual windings around each annular part. A second possibility is that the control winding and/or the third main winding form individual windings around each annular part.

The fourth embodiment will be the one which will be preferred in principle.

The device according to the invention will have many interesting applications, of which we shall mention only a few. These are: a) as a component in a frequency converter for converting input frequency to randomly selected output frequency preferably intended for operation of an asynchronous motor, in a cycloconverter connection, b) as a connector in a frequency converter for converting input frequency to randomly selected output frequency and intended for operation of an asynchronous motor, for addition of parts of the phase voltage generated from a 6 or 12-pulse transformer to each motor phase, c) as a DC to AC converter which converts DC voltage/current to an AC voltage/current of randomly selected output frequency, d) as in c) but where three such variable inductance voltage converters are interconnected in order to generate a three-phase voltage with randomly selected output frequency which is connected to the said asynchronous machine, e) for converting AC voltage to DC voltage within the processing industry, where the device is used as a reluctance-controlled variable transformer where the output voltage is proportional to the reluctance change in a core which is magnetically connected in parallel or in series to an external or internal core with a separate secondary winding, and where three or more such reluctance-controlled transformers are connected to the known three-phase rectifier connections for 6 or 12-pulse rectifier connections for diode output stage, f) for use in a rectifier for converting AC voltage to DC voltage for use in the processing industry, where the device forms voltage connectors which are used as variable inductances in series with primary windings on known transformer connectors, and where three or more such transformers are connected to three-phase rectifier connectors for 6 or 12-pulse rectifier connectors for diode output stage, g) for AC/DC or DC/AC converters for use in the field of switched power supply, for

reduction of the size of the magnetic voltage converter, where the device forms a reluctance-controlled variable transformer where the output voltage is proportional to the reluctance change in a core which is magnetically connected in parallel or in series to an external or internal core with a separate secondary winding, preferably by filters in which inductance is included being formed with a variable inductance, h) as a component in a controllable voltage compensator in the high voltage distribution network, where the device forms a linear variable inductance, i) as a component in a controllable reactive power compensator (VAR compensator), where the device creates linear variable inductance in connection with known filter circuits in which at least one condenser also forms an element, the device in the form of a reluctance-controlled transformer being employed as an element in a compensator connection where capacitance or inductance are automatically connected and adjusted to the extent required to compensate for the reactive power, j) in a system for reluctance-controlled direct conversion of an AC voltage to a DC voltage, k) in a system for reluctance-controlled direct conversion of a DC voltage to an AC voltage.

The voltage connector is without movable parts for absorbing electrical voltage between a generator and a load. The function of the connector is to be able to control the voltage between the generator and the load from 0-100% by means of a small control current. A second function will be as a pure voltage switch or as a current regulator. A further function could be forming and converting of a voltage curve.

The new technology according to the invention will be able to be used for upgrading existing diode rectifiers where there is a need for regulation. In connection with 12-pulse or 24-pulse rectifier systems, it will be possible to balance voltages in the system in a simple manner while having controllable diode rectification from 0-100%.

The current or voltage regulator according to the invention is implemented in the form of a magnetic connector substantially without movable parts, and it will be able to be used for connecting and thereby transferring electrical energy between a generator and a load. The function of the magnetic connector is to be capable of closing and opening an electrical circuit.

The connector will therefore act in a different way to a transductor where the transformer principle is employed in order to saturate the core. The present connector controls the working voltage by bringing the main core with a main winding in and out of saturation by means of a control winding. The connector has no noticeable transformative or inductive connection between the control winding and the main winding (in contrast to a transductor), i.e. no noticeable common flux is produced for the control winding and the main winding.

This new magnetically controlled connector technology will be capable of replacing semiconductors such as GTO's in high-powered applications, and MosFet or IGBT in other applications, except that it will be limited to applications which can withstand stray currents which are produced by the main winding's magnetisation no-load current. As mentioned in the introduction, the new converter will be particularly suitable for realising a frequency converter which converts alternating current power with a given frequency to alternating current power which has a different selected output frequency. No intermediate DC connection will be necessary in this case.

As mentioned at the beginning, the device according to the invention is capable of being employed in connection with frequency converters, such as those based on the cycloconverter principle, but also frequency converters based on 12-pulse bridge converters, or by direct conversion of DC voltage to AC voltage of variable frequency.

The principle of the device according to the invention, where a variable reluctance is employed in a magnetisable body or main core, is based on the fact that magnetisation current in a main winding, which is wound round a main core, is limited by the flux resistance according to Faraday's Law. The flux which has to be established in order to generate counter-induced voltage is dependent on the flux resistance in the magnetic core. The magnitude of the magnetisation current is determined by the amount of flux which has to be established in order to balance applied voltage.

The flux resistance in a coil where the core is air is of the order of 1.000 - 900.000 times greater than for a winding which is wound round a core of ferromagnetic material. In the case of low flux resistance (iron core) little current is required to establish a flux which is necessary to generate a

bucking voltage to the applied voltage, according to Faraday's Law. In the case of high flux resistance (air core) a large current is required in order to establish the flux necessary to generate the same induced bucking voltage.

By controlling the flux resistance, the magnetisation current or the load current in the circuit can be controlled. In order to control the flux resistance, according to the invention a saturation of the main core is employed by means of a control flux which is orthogonal relative to the flux generated by the main winding. As already mentioned, the above-mentioned principle forms the basis of the invention, which relates to a magnetically influenced current or voltage regulator (connector) and a magnetically influenced converter device.

It will be appreciated that both the connector and the converter can be produced by means of suitable production equipment for toroidal cores. From the technical point of view, the converter can be produced by magnetic material such as electroplating being wound up in suitably designed cylindrical cores or used for higher frequencies with compressed powder or ferrite. It is, of course, also advantageous to produce ferrite cores or compressed powder cores according to the dictates of the application.

The invention will now be described in greater detail with reference to the attached drawings, in which:

figs. 1 and 2 illustrate the basic principle of the invention and a first embodiment thereof.
Fig. 3 is a schematic illustration of an embodiment of the device according to the invention.
Fig. 4 illustrates the areas of the different magnetic fluxes which form part of the device according to the invention.
Fig. 5 illustrates a first equivalent circuit for the device according to the invention.
Fig. 6 is a simplified block diagram of the device according to the invention.
Fig. 7 is a diagram for flux versus current.
Figs. 8 and 9 illustrate magnetisation curves and domains for the magnetic material in the device according to the invention.
Fig. 10 illustrates flux densities for the main and control windings.
Fig. 11 illustrates a second embodiment of the invention.

Fig. 12 illustrates the same second embodiment of the invention.

Figs. 13 and 14 illustrate the second embodiment in section.

Figs. 15-18 illustrate different embodiments of the magnetic field connectors in the said second embodiment of the invention.

Figs. 19-32 illustrate different embodiments of the tubular bodies in the second embodiment of the invention.

Figs. 33-38 illustrate different aspects of the magnetic field connectors for use in the second embodiment of the invention.

Fig. 39 illustrates an assembled device according to the second embodiment of the invention.

Figs. 40 and 41 are a section and a view of a third embodiment of the invention.

Figs. 42, 43 and 44 illustrate special embodiments of magnetic field connectors for use in the third embodiment of the invention.

Fig. 45 illustrates the third embodiment of the invention adapted for use as a transformer.

Figs. 46 and 47 are a section and a view of a fourth embodiment of the invention for use as a reluctance-controlled, flux-connected transformer.

Figs. 48 and 49 illustrate the fourth embodiment of the invention adapted to suit a powder-based magnetic material, and thereby without magnetic field connectors.

Figs. 50 and 51 are sections along lines VI-VI and V-V in figure 48.

Figs. 52 and 53 illustrate a core adapted to suit a powder-based magnetic material, and thereby without magnetic field connectors.

Fig. 54 is an "X-ray picture" of a variant of the fourth embodiment of the invention.

Fig. 55 illustrates a second variant of the device according to the invention together with the principle behind a possibility for transformer connection.

Fig. 56 illustrates a proposal for an electro-technical schematic symbol for the voltage connector according to the invention.

Fig. 57 illustrates a proposal for a block schematic symbol for the voltage connector.

Fig. 58 illustrates a magnetic circuit where the control winding and control flux are not included.

In figs. 59 and 60 there are proposals for electro-technical schematic symbols for the voltage converter according to the invention.

Fig. 61 illustrates the use of the invention in an alternating current circuit.

Fig. 62 illustrates the use of the invention in a three-phase system.

Fig. 63 illustrates a use as a variable choke in DC-DC converters.

Fig. 64 illustrates a use as a variable choke in a filter together with condensers.

Fig. 65 illustrates a simplified reluctance model for the device according to the invention and a simplified electrical equivalent diagram for the connector according to the invention.

Fig. 66 illustrates the connection for a magnetic switch.

Fig. 67 illustrates examples of a three-phase use of the invention.

Fig. 68 illustrates the device employed as a switch.

Fig. 69 illustrates a circuit comprising 6 devices according to the invention.

Fig. 70 illustrates the use of the device according to the invention as a DC-AC converter.

Fig. 71 illustrates a use of the device according to the invention as an AC-DC converter.

The invention will now be explained in principle in connection with figs. 1a and 1b.

In the entire description, the arrows associated with magnetic field and flux will substantially indicate the directions thereof within the magnetic material. The arrows are drawn on the outside for the sake of clarity.

Figure 1a illustrates a device comprising a body 1 of a magnetisable material which forms a closed magnetic circuit. This magnetisable body or core 1 may be annular or of another suitable shape. Round the body 1 is wound a first main winding 2, and the direction of the magnetic field H1 (corresponding to the direction of the flux density B1) which will be created when the main winding 2 is excited will follow the magnetic circuit. The main winding 2 corresponds to a winding in an ordinary transformer. In an embodiment the device includes a second main winding 3 which in the same way as the main winding 2 is wound round the magnetisable body 1 and which will thereby provide a magnetic field which extends substantially along the body 1 (i.e. parallel to H1, B1). The device finally includes a third main winding 4 which in a preferred embodiment of the invention extends internally along the magnetic body 1. The magnetic field H2 (and thus the magnetic flux density B2) which is created when the third main winding 4 is excited will have a direction which is at right angles to the direction of the fields in the first and

the second main winding (direction of H1, B1). The invention may also include a fourth main winding 5 which is wound round a leg of the body 1. When the fourth main winding 5 is excited, it will produce a magnetic field with a direction which is at right angles both to the field in the first (H1), the second and the third main winding (H2) (figure 3). This will naturally require the use of a closed magnetic circuit for the field which is created by the fourth main winding. This circuit is not illustrated in the figure, since the figure is only intended to illustrate the relative positions of the windings.

In the topologies which are considered to be preferred in the present description, however, it is the case that the turns in the main winding follow the field direction from the control field and the turns in the control winding follow the field direction to the main field.

Figures 1b-1g illustrate the definition of the axes and the direction of the different windings and the magnetic body. With regard to the windings, we shall call the axis the perpendicular to the surface which is restricted by each turn. The main winding 2 will have an axis A2, the main winding 3 an axis A3 and the control winding 4 an axis A4.

With regard to the magnetisable body, the longitudinal direction will vary with respect to the shape. If the body is elongated, the longitudinal direction A1 will correspond to the body's longitudinal axis. If the magnetic body is square as illustrated in figure 1a, a longitudinal direction A1 can be defined for each leg of the square. Where the body is tubular, the longitudinal direction A1 will be the tube's axis, and for an annular body the longitudinal direction A1 will follow the ring's circumference.

The invention is based on the possibility of altering the characteristics of the magnetisable body 1 in relation to a first magnetic field by altering a second magnetic field which is at right angles to the first. Thus, for example, the field H1 can be defined as the working field and control the body's 1 characteristics (and thereby the behaviour of the working field H1) by means of the field H2 (hereinafter called control field H2). This will now be explained in more detail.

The magnetisation current in an electrical conductor which is enclosed by a ferromagnetic material is limited by the reluctance according to Faraday's Law. The flux which has to be established in order to generate

counterinduced voltage depends on the reluctance in the magnetic material enclosing the conductor.

The extent of the magnetisation current is determined by the amount of flux which has to be established in order to balance applied voltage. In general the following steady-state equation applies for sinusoidal voltage:

1) Flux:

$$\Phi = -j \frac{1}{N.\omega} \cdot E$$

E = applied voltage
ω = angular frequency
N = number of turns for winding

where the flux Φ through the magnetic material is determined by the voltage E. The current required in order to establish necessary flux is determined by:

2) Current

$$I = \Phi \cdot \frac{Rm}{N} \qquad \Phi = \frac{I}{Rm} \cdot N$$

3) Reluctance (flux resistance)

$$Rm = \frac{lj}{\mu_0 \cdot \mu r \cdot Aj}$$

lj = length of flux path
μr = relative permeability
μo = permeability in vacuum
Aj = cross-sectional area of the flux path

Where there is low reluctance (iron enclosure), according to expression 2) above, little current will be required in order to establish the necessary flux, and supplied voltage will overlay the connector. In the case of high reluctance (air) on the other hand, a large current will be required in order to establish the necessary flux. In this case the current will then be limited by the voltage over the load and the voltage induced in the connector. The difference between reluctance in air and reluctance in magnetic material may be of the order of 1.000 - 900.000.

The magnetic induction or flux density in a magnetic material is determined by the material's relative permeability and the magnetic field intensity. The

magnetic field intensity is generated by the current in a winding arranged round or through the material.

For the systems which have to be evaluated the following applies:

The field intensity

$$\int \overline{H}.\overline{ds} = I.N$$

$\overline{H}$ = field intensity
s = the integration path
I = current in winding
N = number of windings

Flux density or induction:

$$\overline{\beta} = \mu_0 \cdot \mu r\, \overline{H}$$

$\overline{H}$ = magnetic field intensity

The ratio between magnetic induction and field intensity is non-linear, with the result that when the field intensity increases above a certain limit, the flux density will not increase and on account of a saturation phenomenon which is due to the fact that the magnetic domains in a ferromagnetic material are in a state of saturation. Thus it is desirable to provide a control field H2 which is perpendicular to a working field H1 in the magnetic material in order to control the saturation in the magnetisable material, while avoiding magnetic connection between the two fields and thereby avoiding transformative or inductive connection. Transformative connection means a connection where two windings "share" a field, with the result that a change in the field from one winding will lead to a change in the field in the other winding.

One will avoid increasing H to saturation as by a transformative connection where the fluxes will have a common path and will be added together. If the fluxes are orthogonal they will not be added together. For example, by providing the magnetic material as a tube where the main winding or the winding which carries the working current is located inside the tube and is wound in the tube's longitudinal direction, and where the control winding or the winding which carries the control current is wound round the circumference of the tube, the desired effect is achieved. Depending on the

tube dimensions, a small area for the control flux and a large area for the working flux are thereby also achieved.

In the said embodiment, the working flux will travel in the direction along the tube's circumference and have a closed magnetic circuit. The control flux on the other hand will travel in the tube's longitudinal direction and will have to be connected in a closed magnetic circuit, either by two tubes being placed in parallel and a magnetic material connecting the control flux between the two tubes, or by a first tube being placed around a second tube, with the result that the control winding is located between the two tubes, and the end surfaces of the tubes are magnetically interconnected, thereby obtaining a closed path for the control flux. These solutions will be described in greater detail later.

The parts which provide magnetic connection between the tubes or the core parts will hereinafter be called magnetic field connectors or magnetic field couplings.

The total flux in the material is given by

4) $\Phi = B \cdot Aj$

The flux density B is composed of the vector sum of B1 and B2 (fig. 4d). B1 is generated by the current I1 in the first main winding 2, and B1 has a direction tangentially to the conductors in the main winding 2. The main winding 2 has N1 turns and is wound round the magnetisable body 1. B2 is generated by the current I2 in the control winding 4 with N2 number of turns and where the control winding 4 is wound round the body 1. B2 will have a direction tangentially to the conductors in the control winding 4.

Since the windings 2 and 4 are placed at 90° to each other, B1 and B2 will be orthogonally located. In the magnetisable body 1, B1 will be oriented transversally and B2 longitudinally. In this connection we refer particularly to what is illustrated in figs. 1-4.

5) $\overline{B} = \overline{B_1} + \overline{B_2}$

It is considered an advantage that the relative permeability is higher in the working field's (H1) direction than in the control field's (H2) direction, i.e. the magnetic material in the magnetisable body 1 is anisotropic, but of course

this should not be considered limiting with regard to the scope of the invention.

The vector sum of the fields H1 and H2 will determine the total field in the body 1, and thus the body's 1 condition with regard to saturation, and will be determining for the magnetisation current and the voltage which is divided between a load connected to the main winding 2 and the connector. Since the sources for B1 and B2 will be located orthogonally to each other, none of the fields will be able to be decomposed into the other. This means that B1 cannot be a function of B2 and vice versa. However, B, which is the vector sum of B1 and B2 will be influenced by the extent of each of them.

B2 is the vector which is generated by the control current. The cross-sectional surface A2 for the B2 vector will be the transversal surface of the magnetic body 1, cf. figure 4c. This may be a small surface limited by the thickness of the magnetisable body 1, given by the surface sector between the internal and external diameters of the body 1, in the case of an annular body. The cross-sectional surface A1 (see figures 4a, b) for the B1 field on the other hand is given by the length of the magnetic core and the rating of applied voltage. This surface will be able to be 5-10 times larger than the surface of the control flux density B2, without this being considered limiting for the invention.

When B2 is at saturation level, a change in B1 will not result in a change in B. This makes it possible to control which level on B1 gives saturation of the material, and thereby control the reluctance for B.

The inductance for the control winding 4 (with N2 turns) will be able to be rated at a small value suitable for pulsed control of the regulator, i.e. enabling a rapid reaction (of the order of milliseconds) to be provided.

6)

$$Ls = N2^2 \cdot \mu_{r-sat} \cdot \mu_0 \cdot \frac{A2}{l2}$$

N2= Number of turns for control winding
A2 = Area of control flux density B2
l2 = Length of flux path for control flux

A simplified mathematical description will now be given of the invention and its applications, based on Maxwell's equations.

For simple calculations of magnetic fields in electrical power technology, Maxwell's equations are used in integral form.

In a device of the type which will be analysed here (and to some extent also in the invention), the magnetic field has low frequency.

The displacement current can thus be neglected compared with the current density.
Maxwell's equation

$$\mathrm{curl}\left(\overline{H}\right) = \overline{J} + \frac{d}{dt}\overline{D} \qquad 7)$$

is simplified to

$$\mathrm{curl}\left(\overline{H}\right) = \overline{J} \qquad 8)$$

The integral form is found in Toke's theorem:

$$\int\left(\overline{H}\right)\overline{dl} = I \qquad 9)$$

presents a solution for the system in fig. 4, where the main winding 2 establishes the H1 field. The calculations are performed here with concentrated windings in order to be able to focus on the principle and not an exact calculation.

The integration path coincides with the field direction and an average field length 11 is chosen in the magnetisable body 1. The solution of the integral equation then becomes:

$$H_1 l_1 = N_1 \cdot I_1 \qquad 11)$$

This is also known as the magnetomotive force MMK.

$$F_1 = N_1 \cdot I_1 \qquad 12)$$

The control winding 4 will establish a corresponding MMK generated by the current I2:

$$H_2 \cdot I_2 = N_2 \cdot I_2 \qquad 13)$$

$$F_2 = N_2 \cdot I_2 \qquad 14)$$

The magnetisation of the material under the influence of the H field which is generated from the source windings 2 and 4 is expressed by the flux density B. For the main winding 2:

$$\overline{B_1} = \mu_0 \cdot \mu r_1 \cdot \overline{H}_1 \qquad 15)$$

For the control winding 4:

$$\overline{B_2} = \mu_0 \cdot \mu r_2 \cdot \overline{H}_2 \qquad 16)$$

The permeability in the transversal direction is of the order of 1 to 2 decades less than for the longitudinal direction. The permeability for vacuum is:

$$\mu_0 = 4 \cdot \pi \cdot 10^{-7} \cdot \frac{H}{m} \qquad 17)$$

The capacity to conduct magnetic fields in iron is given by μ_r, and the magnitude of μ is from 1000 to 100.000 for iron and for the new Metglas materials up to 900.000.

By combining equations 11) and 15), for the main winding 2 we get:

$$B_1 = \mu_0 \cdot \mu_r \cdot \frac{N_1 \cdot I_1}{l_1} \qquad 18)$$

The flux in the magnetisable body 1 from the main winding 2 is given by equation:

$$\Phi_1 = \int_{Aj}^{0} \overline{B}_1 \cdot \overline{n}\, ds \qquad 19)$$

Assuming the flux is constant over the core cross section:

$$\Phi_1 = B_1 \cdot A_1 = \mu_0 \cdot \mu_r \frac{N_1 I_1 A_1}{l_1} \qquad 20)$$

Here we recognise the expression for the flux resistance Rm or the reluctance as given under 3):

$$\Phi_1 = \frac{N_1 I_1}{Rml} \qquad 21)$$

$$Rm_1 = \frac{l_1}{\mu_0 \cdot \mu_r \cdot A_1} \qquad 22)$$

In the same way we find flux and reluctance for the control winding 4:

$$\Phi_2 = \frac{N_2 \cdot I_2}{Rm_2} \qquad 23)$$

$$Rm_2 = \frac{I_2}{\mu_0 \cdot \mu r_2 \cdot A_2} \qquad 24)$$

The invention is based on the physical fact that the differential of the magnetic field intensity which has its source in the current in a conductor is expressed by curl to the H field. Curl to H says something about the differential or the field change of the H field across the field direction of H. In our case we have calculated the field on the basis that the surface perpendicular of the differential field loop has the same direction as the current. This means that the fields from the current-carrying conductors forming the windings which are perpendicular to each other are also orthogonal. The fact that the fields are perpendicular to each other is important in relation to the orientation of the domains in the material.

Before examining this more closely, let us introduce self-inductance which will play a major role in the application of the new magnetically controlled power components.

According to Maxwell's equations, a time-varying magnetic field will induce a time-varying electrical field, expressed by

$$\int \overline{E}.\overline{dl} = \frac{d}{dt}\left(\int_S \overline{B} \cdot \overline{n}\, ds\right) \qquad 25)$$

The left side of the integral is an expression of the potential equation in integral form. The source of the field variation may be the voltage from a

generator and we can express Faraday's Law when the winding has N turns and all flux passes through all the turns, see fig. 5:

$$e = N \cdot A_j \cdot \frac{d}{dt} B = N \cdot \frac{d}{dt} \Phi = \frac{d}{dt} \lambda \qquad 26)$$

λ (Wb) gives an expression of the number of flux turns and is the sum of the flux through each turn in the winding. If one envisages the generator G in fig. 5 being disconnected after the field is established, the source of the field variation will be the current in the circuit and from circuit technology we have, see fig. 5a:

$$e = L \cdot \frac{di}{dt} \qquad 27)$$

From equation 21 we have:

$$\Phi = k \cdot I \qquad 28)$$

When L is constant, the combination of equations 26 and 27 gives:

$$\frac{d\lambda}{dt} = L \frac{di}{dt} \qquad 29)$$

The solution of 29 is:

$$\lambda = L \cdot i + C \qquad 30)$$

From 28 we derive that C is 0 and:

$$L = \frac{\lambda}{i} \qquad 31)$$

This is an expression of self-inductance for the winding N (or in our case the main winding 2). The self-inductance is equal to the ratio between the flux turns established by the current in the winding (the coil) and the current in the winding (the coil).

The self-inductance in the winding is approximately linear as long as the magnetisable body or the core are not in saturation. However, we shall change the self-inductance through changes in the permeability in the

material of the magnetisable body by changing the domain magnetisation in the transversal direction by the control field (i.e. by the field H2 which is established by the control winding 4).

From equation 21) combined with 31) we obtain:

$$L = \frac{N^2}{Rm} \qquad 32)$$

The alternating current resistance or the reactance in an electrical circuit with self-inductance is given by

$$X_L = jwL \qquad 33)$$

By magnetising the domains in the magnetisable body in the transversal direction, the reluctance of the longitudinal direction will be changed. We shall not go into details here in the description of what happens to the domains during different field influences. Here we have considered ordinary commercial electroplate with a silicon content of approximately 3%, and in this description we shall not offer an explanation of the phenomenon in relation to the Metglas materials, but this, of course, should not be considered limiting for the invention, since the magnetic materials with amorphous structure will be able to play an important role in some applications of the invention.

In a transformer we employ closed cores with high permeability where energy is stored in magnetic leakage fields and a small amount in the core, but the stored energy does not form a direct part in the transformation of energy, with the result that no energy conversion takes place in the sense of what occurs in an electromechanical system where electrical energy is converted to mechanical energy, but energy is transformed via magnetic flux through the transformer. In an inductance coil or choke with an air gap, the reluctance in the air gap is dominant compared to the reluctance in the core, with approximately all the energy being stored in the air gap.

In the device according to the invention a "virtual" air gap is generated through saturation phenomena in the domains. In this case the energy storage will take place in a distributed air gap comprising the whole core. We

consider the actual magnetic energy storage system to be free for losses, and any losses will thus be represented by external components.

The energy description which we use will be based on the principle of conservation of energy.

The first law of thermodynamics applied to the loss-free electromagnetic system above gives, see fig. 6:

$$dWelin = dWfld \qquad 34)$$

where $dWelin$ = differential electrical energy supply
$dWfld$ = differential change in magnetically stored energy

From equation 26) we have

$$e = \frac{d}{dt}\lambda$$

Now our inductance is variable through the orthogonal field or the control field H2, and equation 31) inserted in 26) gives:

$$e = \frac{d(L \cdot i)}{dt} = L \cdot \frac{di}{dt} + i \cdot \frac{dL}{dt} \qquad 35)$$

The effect within the system is

$$p = i \cdot e = i \cdot \frac{d}{dt}\lambda \qquad 36)$$

Thus we have

$$dW_{elin} = i \cdot d\lambda \qquad 37)$$

For a system with a core where the reluctance can be varied and which only has a main winding, equation 35) inserted in equation 37) will give

$$dW_{elin} = i \cdot d(L \cdot i) = i \cdot (L \cdot di + i \cdot dl) \qquad 38)$$

In the device according to the invention L will be varied as a function of μr, the relative permeability in the magnetisable body or the core 1, which in turn is a function of I2, the control current in the control winding 4.

When L is constant, i.e. when I2 is constant, we can disregard the section i x dL since dL is equal to 0, and thus the magnetic field energy will be given by:

$$W_{flt} = \frac{1}{2} \cdot L \cdot i^2 \qquad 39)$$

When L is varied by means of I2, the field energy will be altered as a result of the altered value of L, and thereby the current I will also be altered since it is associated with the field value through the flux turns λ. Since i and λ are variable and functions of each other, while being non-linear functions, we shall not go into the solution here since it will involve mathematics which exceed the bounds of the description of the invention.

However, we can draw the conclusion that the field energy and the energy distribution will be controllable via μr and influence how energy stored in the field is increased and decreased. When the field energy is decreased, the surplus portion will be returned to the generator. Or if we have an extra winding (e.g. winding 3, figure 1) in the same winding window as the first main winding 2 and with the same winding axis as it has, this will provide a transformative transfer of energy from the first winding 2 to the second main winding 3.

This is illustrated in fig. 7 where an alteration of λ results in an alteration of the energy in the field Wflt which originally is Wflt(λo, io). A variation is envisaged here which is so small that i is approximately constant during the alteration of λ. In the same way an alteration of i will give an alteration of λ. When we look at our variable inductance, therefore, we can say the following:

The substance of what takes place is illustrated in fig. 8 and fig. 9.

Fig. 8 illustrates the magnetisation curves for the entire material of the magnetisable body 1 and the domain change under the influence of the H1 field from the main winding 2.

Fig. 9 illustrates the magnetisation curves for the entire material of the magnetisable body 1 and the domain change under the influence of the H2 field in the direction from the control winding 4.

Figs. 10a and 10b illustrate the flux densities B1 (where the field H1 is established by the working current), and B2 (corresponding to the control current). The ellipse illustrates the saturation limit for the B fields, i.e. when the B field reaches the limit, this will cause the material of the magnetisable body 1 to reach saturation. The form of the ellipse's axes will be given by the field length and the permeability of the two fields B1 (H1) and B2 (H2) in the core material of the magnetisable body 1.

By having the axes in figure 10 express the MMK distribution or the H field distribution, a picture can be seen of the magnetomotive force from the two currents I1 and I2.

We now refer back to figures 8 and 9. By means of a partial magnetisation of the domains by the control field B2 (H2), an additional field B1 (H1) from the main winding 2 will be added vectorially to the control field B2 (H2), further magnetising the domains, with the result that the inductance of the main winding 2 will start from the basis given by the state of the domains under the influence of the control field B2 (H2).

The domain magnetisation, the inductance L and the alternating current resistance XL will thereby be varied linearly as a function of the control field B2.

We shall now describe the various embodiments of the device according to the invention, with reference to the remaining figures.

Figure 11 is a schematic illustration of a second embodiment of the invention.

Figure 12 illustrates the same embodiment of a magnetically influenced connector according to the invention, where fig. 12a illustrates the assembled connector and fig. 12b illustrates the connector viewed from the end.

Figure 13 illustrates a section along line II in figure 12b.

As illustrated in the figures the magnetisable body 1 is composed of inter alia two parallel tubes 6 and 7 made of magnetisable material. An electrically

insulated conductor 8 (figs. 12a, 13) is passed continuously in a path through the first tube 6 and the second tube 7 N number of times, where N = 1, ... r, forming the first main winding 2, with the conductor 8 extending in the opposite direction through the two tubes 6 and 7, as is clearly illustrated in fig. 13. Even though the conductor 8 is only shown extending through the first tube 6 and the second tube 7 twice, it should be self-explanatory that it is possible for the conductor 8 to extend through respective tubes either only once or possibly several times (as indicated by the fact that the winding number N can vary from 0 to r), thus creating a magnetic field H1 in the parallel tubes 6 and 7 when the conductor is excited. A combined control and magnetisation winding 4, 4', composed of the conductor 9, is wound round the first tube and the second tube (6 and 7 respectively) in such a manner that the direction of the field H2 (B2) which is created in the said tubes when the winding 4 is excited will be oppositely directed, as indicated by the arrows for the field B2 (H2) in figure 11. The magnetic field connectors 10, 11 are mounted at the ends of the respective pipes 6, 7 in order to interconnect the tubes fieldwise in a loop. The conductor 8 will be able to carry a load current I1 (fig. 12a). The tubes' 6, 7 length and diameter will be determined on the basis of the power and voltage which have to be connected. The number of turns N1 on the main winding 2 will be determined by the reverse blocking ability for voltage and the cross-sectional area of the extent of the working flux ϕ2. The number of turns N2 on the control winding 4 is determined by the fields required for saturation of the magnetisable body 1, which comprises the tubes 6, 7 and the magnetic field connectors 10, 11.

Figure 14 illustrates a special design of the main winding 2 in the device according to the invention. In reality, the solution in fig. 14 differs from that illustrated in figs. 12 and 13 only by the fact that instead of a single insulated conductor 8 which is passed through the pipes 6 and 7, two separate oppositely directed conductors, so-called primary conductors 8 and secondary conductors 8' are employed, in order thereby to achieve a voltage converter function for the magnetically influenced device according to the invention. This will now be explained in more detail. The design is basically similar to that illustrated in figs. 11, 12 and 13. The magnetisable body 1 comprises two parallel tubes 6 and 7. An electrically insulated primary conductor 8 is passed continuously in a path through the first tube 6 and the second tube 7 N1 number of times, where N1 = 1, ... r, with the primary

conductor 8 extending in the opposite direction through the two tubes 6 and 7. An electrically insulated secondary conductor 8' is passed continuously in a path through the first tube 6 and the second tube 7 N1' number of times, where N1' = 1, ... r, with the secondary conductor 8' extending in the opposite direction relative to the primary conductor 8 through the two tubes 6 and 7. At least one combined control and magnetisation winding 4 and 4' is wound round the first tube 6 and the second tube 7 respectively, with the result that the field direction created on the said tube is oppositely directed. As for the embodiment according to figs. 11, 12 and 13, magnetic field connectors 10, 11 are mounted on the end of respective tubes (6, 7) in order to interconnect the tubes 6 and 7 fieldwise in a loop, thereby forming the magnetisable body 1. Even though for the sake of simplicity the primary conductor 8 and the secondary conductor 8' are illustrated in the drawings with only one pass through the tubes 6 and 7, it will be immediately apparent that both the primary conductor 8 and the secondary conductor 8' will be able to be passed through the tubes 6 and 7 N1 and N1' number of times respectively. The tubes' 6 and 7 length and diameter will be determined on the basis of the power and voltage which have to be converted. For a transformer with a conversion ratio (N1:N1') equal to 10:1, in practice ten conductors will be used as primary conductors 8 and only one secondary conductor 8'.

An embodiment of magnetic field connectors 10 and/or 11 is illustrated in figure 15. A magnetic field connector 10, 11 is illustrated, composed of a magnetically conducting material, wherein two preferably circular apertures 12 for the conductor 8 in the main winding 2 (see, e.g. fig. 13) are machined out of the magnetic material in the connectors 10, 11. Moreover, there is provided a gap 13 which interrupts the magnetic field path of the conductor 8. End surface 14 is the connecting surface for the magnetic field H2 from the control winding 4 consisting of conductors 9 and 9' (fig. 13).

Fig. 16 illustrates a thin insulating film 15 which will be placed between the end surface on tubes 6 and 7 and the magnetic field connector 10, 11 in a preferred embodiment of the invention.

Figures 17 and 18 illustrate other alternative embodiments of the magnetic field connectors 10, 11.

Figures 19-32 illustrate various embodiments of a core 16 which in the embodiment illustrated in figures 12, 13 and 14 forms the main part of the tubes 6 and 7 which preferably together with the magnetic field connectors 10 and 11 form the magnetisable body 1.

Fig. 19 illustrates a cylindrical core part 16 which is divided lengthwise as illustrated and where there are placed one or more layers 17 of an insulating material between the two core halves 16', 16".

Fig. 20 illustrates a rectangular core part 16 and fig. 21 illustrates an embodiment of this core part 16 where it is divided in two with partial sections in the lateral surface. In the embodiment illustrated in fig. 21, one or more layers of an insulating material 17 are provided between the core halves 16, 16'. A further variant is illustrated in figure 22 where the partial section is placed in each corner.

Figs. 23, 24 and 25 illustrate a rectangular shape. Figures 26, 27 and 28 illustrate the same for a triangular shape. Figs. 29 and 30 illustrate an oval variant, and finally figures 31 and 32 illustrate a hexagonal shape. In figure 31 the hexagonal shape is composed of 6 equal surfaces 18 and in fig. 30 the hexagon consists of two parts 16' and 16". Reference numeral 17 refers to a thin insulating film.

Figures 33 and 34 illustrate a magnetic field connector 10, 11 which can be used as a control field connector between the rectangular and square main cores 16 (illustrated in figures 20-21 and 23-25 respectively). This magnetic field connector comprises three parts 10', 10" and 19.

Fig. 34 illustrates an embodiment of the core part or main core 16 where the end surface 14 or the connecting surface for the control flux is at right angles to the axis of the core part 16.

Fig. 35 illustrates a second embodiment of the core part 16 where the connecting surface 14 for the control flux is at an angle α to the axis of the core part 16.

Figures 36-38 illustrate various designs of the magnetic field connector 10, 11, which are based on the fact that the connecting surfaces 14' of the magnetic field connector 10, 11 are at the same angle as the end surfaces 14 to the core part 16.

Fig. 36 illustrates a magnetic field connector 10, 11 in which different hole shapes 12 are indicated for the main winding 2 on the basis of the shape of the core part 16 (round, triangular, etc.).

In fig. 37 the magnetic connector 10, 11 is flat. It is adapted for use with core parts 16 with right-angled end surfaces 14.

In fig. 38 an angle α' is indicated to the magnetic field connector 10, 11, which is adapted to the angle α to the core part (figure 35), thus causing the end surface 14 and the connecting surface 14' to coincide.

In fig. 39 a an embodiment of the invention is illustrated with an assembly of magnetic field connectors 10, 11 and core parts 16. Figure 39b illustrates the same embodiment viewed from the side.

Even though only individual combinations of magnetic field connectors and core parts are described in order to illustrate the invention, it will be obvious to a person skilled in the art that other combinations are entirely possible and will thus fall within the scope of the invention.

It will also be possible to switch the positions of the control winding and the main winding.

Figures 40 and 41 are a sectional illustration and view respectively of a third embodiment of a magnetically influenced voltage connector device. The device comprises (see figure 40b) a magnetisable body 1 comprising an external tube 20 and an internal tube 21 (or core parts 16, 16') which are concentric and made of a magnetisable material with a gap 22 between the external tube's 20 inner wall and the internal tube's 21 outer wall. Magnetic field connectors 10, 11 between the tubes 20 and 21 are mounted at respective ends thereof (fig. 40a). A spacer 23 (fig. 40a) is placed in the gap 22, thus keeping the tubes 20, 21 concentric. A combined control and magnetisation winding 4 composed of conductors 9 is wound round the internal tube 21 and is located in the said gap 22. The winding axis A2 for the control winding therefore coincides with the axis A1 of the tubes 20 and 21. An electrical current-carrying or main winding 2 composed of the current conductor 8 is passed through the internal tube 21 and along the outside of the external tube 20 N1 number of times, where N1 = 1, ... r. With the combined control and magnetisation winding 4 in co-operation with the main

winding 2 or the said current-carrying conductor 8, an easily constructed but efficient magnetically influenced voltage connector is obtained. This embodiment of the device may also be modified in such a manner that the tubes 20, 21 do not have a circular cross section, but a cross section which is square, rectangular, triangular, etc.

It is also possible to wind the main winding round the internal tube 21, in which case the axis A2 of the main winding will coincide with the axis A1 of the tubes, while the control winding is wound about the tubes on the inside of 21 and the outside of 20.

Figs. 42-44 illustrate various embodiments of the magnetic field connector 10, 11 which are specially adapted to the latter design of the invention, i.e. as described in connection with figures 40 and 41.

Figure 42a illustrates in section and figure 42b in a view from above a magnetic field connector 10, 11 with connecting surfaces 14' at an angle relative to the axis of the tubes 20, 21 (the core parts 16) and it is obvious that the internal 21 and external 20 tubes should also be at the same angle to the connecting surfaces 14.

Figures 43 and 44 illustrate other variants of the magnetic field connector 10, 11, where the connecting surfaces 14' of the control field H2 (B2) are perpendicular to the main axis of the core parts 16 (tubes 20, 21).
Figure 43 illustrates a hollow semi-toroidal magnetic field connector 10, 11 with a hollow semi-circular cross section, while figure 44 illustrates a toroidal magnetic field connector with a rectangular cross section.

A variant of the device illustrated in figures 40 and 41 is illustrated in fig. 45, where figure 45a illustrates the device from the side while 45b illustrates it from above. The only difference from the voltage connector in figs. 40-41 is that a second main winding 3 is wound in the same course as the main winding 2. By this means an easily constructed, but efficient magnetically influenced voltage converter is obtained.

Figures 46 and 47 are a section and a view illustrating a fourth embodiment of the voltage connector with concentric tubes.

Figures 46 and 47 illustrate the voltage connector which acts as a voltage converter with joined cores. An internal reluctance-controlled core 24 is

located within an external core 25 round which is wound a main winding 2. The reluctance-controlled internal core 24 has the same construction as mentioned previously under the description of figs. 40 and 41, but the only difference is that there is no main winding 2 round the core 24. It has only a control winding 4 which is located in the gap 22 between the inner 21 and outer parts forming the internal reluctance-controlled core 24, with the result that only core 24 is magnetically reluctance-controlled under the influence of a control field H2 (B2) from current in the control winding 4.

The main winding 2 in figs. 46 and 47 is a winding which encloses both core 24 and core 25.

The mode of operation of the reluctance-controlled voltage connector or converter according to the invention and described in connection with figures 46 and 47 will now be described.

We shall also refer to figure 55 which illustrates the principle of the connection, figure 65 with a simplified equivalent diagram for the reluctance model where Rmk is the variable reluctance which controls the flux between the windings 2 and 3, and figure 65b which illustrates an equivalent electrical circuit for the connection where Lk is the variable inductance.

An alternating voltage V1 over winding 2 will establish a magnetisation current I1 in winding 2. This is generated by the flux $\phi 1 + \phi 1'$ in the cores 24 and 25 which requires to be established in order to provide the bucking voltage which according to Faraday's Law is generated in 2. When there is no control current in the reluctance-controlled core 24, the flux will be divided between the cores 24 and 25 based on the reluctance in the respective cores 24 and 25.

In order to bring energy through from one winding to the other, the internal reluctance-controlled core 24 has to be supplied with control current I2.

By supplying control current I2 in the positive half-period of the alternating voltage V1 in 2, we shall obtain a half-period voltage over 2. Since the energy is transferred by flux displacement between the reluctance-controlled core 24 and the external (secondary) core 25, the reluctance-controlled core 24 will essentially be influenced by the control current I2 during the period when it is controlled in saturation, while the working flux will travel in the

secondary external core 25 and interact with the primary winding 2 during the energy transfer.

When the reluctance-controlled core 24 is brought out of saturation by resetting the control flux B2 (H2) which is orthogonal to the working flux B1 (H1), the flux from the primary side will again be divided between the cores 24 and 25, and a load connected to the secondary winding 3 will only see a low reluctance and thereby high inductance and little connection between primary (VI) and secondary (V3) voltage. A voltage will be generated over the secondary winding 3, but on account of the magnitude of Lk compared to the magnetisation impedance Lm, most of the voltage (V1) from the primary winding 2 will overlay Lk. The flux from the primary winding 2 will essentially go where there is the least reluctance and where the flux path is shortest (fig. 65b).

It may also be envisaged that the external core 25 could be made controllable, in addition to having a fourth main winding wound round the internal controllable core 24. This is to enable the voltage between the cores 24 and 25 to be controlled as required.

Fig. 48 describes a further variant of the fourth embodiment of a magnetically influenced voltage connector or voltage converter according to the invention, where the magnetisable body 1 is so designed that the control flux B2 (H2) is connected directly without a separate magnetic field connector through the main core 16.

Fig. 48 illustrates a voltage connector in the form of a toroid viewed from the side. The voltage connector comprises two core parts 16 and 16', a main winding 2 and a control winding 4.

Fig. 49 illustrates a voltage connector according to the invention equipped with an extra main winding 3 which offers the possibility of converting the voltage.

Fig. 50 illustrates the device in figure 48 in section along line VI-VI in figure 48 and figure 51 illustrates a section along line V-V. In figure 50 a circular aperture 12 is illustrated for placing the control winding 4.

Figure 51 illustrates an additional aperture 26 for passing through wiring.

Figures 52 and 53 illustrate the structure of a core 16 without windings and where the core 16 is so designed that there is no need for an extra magnetic field connector for the control field. The core 16 has two core parts 16, 16' and an aperture 12 for a control winding 4. This design is intended for use where the magnetic material is sintered or compressed powder-moulded material. In this case it will be possible to insert closed magnetic field paths in the topology, with the result that what were previously separate connectors which were required for foil-wound cores form part of the actual core and are a productive part of the structure. The core, which forms the closed magnetic circuit without separate magnetic field connectors and which is illustrated in these figures 52 and 53, will be able to be used in all the embodiments of the invention even though the figures illustrate a body 1 adapted for the first embodiment of the invention (illustrated inter alia in figures 1 and 2).

Figure 54 illustrates a magnetically influenced voltage converter device, where the device has an internal control core 24 consisting of an external tube 20 and an internal tube 21 which are concentric and made of a magnetisable material with a gap 22 between the external tube's 20 inner wall and the internal tube's 21 outer wall. Spacers 23 are mounted in the gap between the external tube's 20 inner wall and the internal tube's 21 outer wall. Magnetic field connectors 10, 11 are mounted between the tubes 20 and 21 at respective ends thereof. A combined control and magnetisation winding 4 is wound round the internal tube 21 and is located in the said gap 22. The device further consists of an external secondary core 25 with windings comprising a plurality of ring core coils 25', 25", 25"' etc. placed on the outside of the control core 24. Each ring core coil 25', 25", 25"' etc. consists of a ring of a magnetisable material wound round by a respective second main winding or secondary winding 3, only one of which is illustrated for the sake of clarity. A first main winding or primary winding 2 is passed through the internal tube 21 in the control core 24 and along the outside of the external cores 25 N1 number of times, where N1 = 1, ... r.

It is also possible to envisage the secondary core device being located within the control core 24, in which case the primary winding 2 will have to be passed through the ring cores 25 and along the outside of the control core 24.

Figure 55 is a schematic illustration of a second embodiment of the magnetically influenced voltage regulator according to the invention with a

first reluctance-controlled core 24 and a second core 25, each of which is composed of a magnetisable material and designed in the form of a closed, magnetic circuit, the said cores being juxtaposed. At least one first electrical conductor 8 is wound on to a main winding 2 about both the first and the second core's cross-sectional profile along at least a part of the said closed circuit. At least one second electrical conductor 9 is mounted as a winding 4 in the reluctance-controlled core 24 in a form which essentially corresponds to the closed circuit. In addition, at least one third electrical conductor 27 is wound round the second core's 25 cross-sectional profile along at least a part of the closed circuit. The field direction from the first conductor's 8 winding 2 and the second conductor's 9 winding is orthogonal. By means of this solution, the first conductor 8 and the third conductor 27 form a primary winding 2 and a secondary winding 3 respectively.

Figure 56 illustrates a proposal for an electro-technical schematic symbol for the voltage connector according to the invention. Fig. 57 illustrates a proposal for a block schematic symbol for the voltage connector.

Figure 58 illustrates a magnetic circuit where the control winding 4 and control flux B2 (H2) are not included.

In figs. 59 and 60 there is a proposal for an electro-technical schematic symbol for the voltage converter where the reluctance in the control core 24 shifts magnetic flux between a core with fixed reluctance 25 and a second core with variable reluctance 24 (see for example figure 55).

There is, of course, no restriction to having two cores with variable reluctance. The fact that we can shift flux between two cores within the same winding will be employed in order to make a magnetic switch which can switch a voltage off and on independently of the course of magnetisation in the main core. This means that we have a switch which has the same function as a GTO, except that we can choose whatever switching time we wish.

The device according to the invention will be able to be used in many different connections and examples will now be given of applications in which it will be particularly suitable.

Figure 61 illustrates the use of the invention in an alternating current circuit in order to control the voltage over a load RL, which may be a light source, a heat source or other load.

Figure 62 illustrates the use of the invention in a three-phase system where such a voltage connector in each phase, connected to a diode bridge, is used for a linear regulation of the output voltage from the diode bridge.

Figure 63 illustrates a use as a variable choke in DC-DC converters.

Figure 64 illustrates a use as a variable choke in a filter together with condensers. Here we have only illustrated a series and a parallel filter (64a and 64b respectively), but it is implicit that the variable inductance can be used in a number of filter topologies.

A further application of the invention is that described inter alia in connection with figures 14 and 45, where proposals for schematic symbols were given in figure 59. In this application, the voltage connector has a function as a voltage converter where a secondary winding is added. An application as a voltage regulator is also illustrated here, where the magnetisation current in the transformer connection and the leakage reactance are controllable via the control winding 4. The special feature of this system is that the transformer equations will apply, while at the same time the magnetisation current can be controlled by changing μr. In this case, therefore, the characteristic of the transformer can be regulated to a certain extent. If there is a DC excitation of one winding 2, it will be possible to obtain transformed energy through the transformer by varying μr and thereby the flux in the reluctance-controlled core instead of varying the excitation. Thus it is possible in principle to generate an AC voltage from a DC voltage by means of the fact that an alteration of the magnetisation current from the DC generator into this system will be able to be transformed to a winding on the secondary side.

Another application of the invention is illustrated in figures 46 and 47, where a variable reluctance as control core is surrounded or enclosed by one or more separate cores with separate windings, as well as figure 55 where a first reluctance-controlled core and a second core are designed as closed magnetic circuits and are juxtaposed. We also refer to figure 65 which illustrates an equivalent electrical circuit.

Figure 55 illustrates how the fluxes in the invention travel in the cores. We wish to emphasise that the flux in the control core is connected to the flux in the working core via the windings enclosing both cores. In this system transformation of electrical energy will be able to be controlled by flux being connected to and disconnected from a control core and a working core. Since the fluxes between the cores are interconnected through Faraday's induction law, the functional dependence of the equations for the primary side and the equations for the secondary side will be controlled by the connection between the fluxes. In a linear application we will be able to control a transformation of voltages and currents between a primary winding and a secondary winding linearly by altering the reluctance in the control core, thus permitting us to introduce here the term reluctance-controlled transformer. For a switched embodiment we will be able to introduce the term reluctance-controlled switch.

The flux connection between the primary or first main winding 2 and the secondary winding or second main winding 3 will now be explained. Winding 2 which now encloses both the reluctance-controlled control core 24 and the main core 25 will establish flux in both cores. The self-inductance L1 to 2 tells how much flux, or how many flux turns are produced in the cores when a current is passed in I1 in 2. The mutual inductance between the primary winding 2 and the secondary winding 3 indicates how many of the flux turns established by 2 and I1 are turned about 2 and about the secondary winding 3.

We may, of course, also envisage the main core 25 being reluctance-controlled, but for the sake of simplicity we shall refer here to a system with a main core 25 where the reluctance is constant, and a control core 24 where the reluctance is variable.

The flux lines will follow the path which gives the highest permeance (where the permeability is highest), i.e. with the least reluctance.

In figs. 55 and 65 we have not taken into consideration the leakage fields in the main windings 2 and 3. Fig. 55 illustrates a simplified model of the transformer where the primary 2 and secondary 3 windings are each wound around a transformer leg, while in practice they will preferably be wound on the same transformer leg, and in our case, for example, the outer ring core

which is the main core 25 will be wound around the secondary winding 3 distributed along the entire core 25. Similarly, the primary winding 2 will be wound around the main core 25 and the control core 24 which may be located concentrically and within the main core.

Figure 65 illustrates a simplified reluctance model for the device according to the invention.

Fig. 65b illustrates a simplified electrical equivalent diagram for the connector according to the invention, where the reluctances are replaced by inductances.

A current in 2 generates flux in the cores 24 and 25:

$$\Phi = \Phi_k + \Phi_1 \qquad 40)$$

where:
Φ_p = total flux established by the current in 2.
Φ_k = the total flux travelling through the control core 24.
Φ_l = part of the total flux travelling through the main core 25.

Since the leakage flux in main core 24 and control core 25 are disregarded,

$$\Phi_1 = -\Phi_2 \qquad 41)$$

In a way Φ_k may be regarded as a controlled leakage flux.

On the basis of fig. 65 we can formulate the highly simplified electrical equivalent diagram for the magnetic circuit illustrated in fig. 65b.

Figure 65b therefore illustrates the principle of the reluctance-controlled connector, where the inductance L_k absorbs the voltage from the primary side.

$$L_k = \frac{\lambda_k}{I} = \frac{NI^2}{R_{mk}} \qquad 42)$$

This inductance is controlled through the variable reluctance in the control core 24, with the result that the connection or the voltage division for a sinusoidal steady-state voltage applied to the primary winding will be approximately equal to the ratio between the inductance in the respective cores as illustrated in equation 43.

$$\frac{e_2}{e_1} = \frac{Lm}{L_k + Lm} \qquad 43)$$

When the control core 24 is in saturation, L_k is very small compared to L_m and the voltage division will be according to the ratio between the number of turns N1/N3. When the control core is in the off state, L_k will be large and to the same extent will block voltage transformation to the secondary side.

The magnetisation of the cores relative to applied voltage and frequency is so rated that the main core 25 and the control core 24 can each separately absorb the entire time voltage integral without going into saturation. In our model the area of iron on the control and working cores is equal without this being considered as limiting for the invention.

Since the control core 24 is not in saturation on account of the main winding 2, we shall be able to reset the control core 24 independently of the working flux B1 (H1), thereby achieving the object by means of the invention of realising a magnetic switch. If necessary the main core 25 may be reset after an on pulse or a half on period by the necessary MMF being returned in the second half-period only in order to compensate for any distortions in the magnetisation current.

In a switched application, when the switch is off, i.e. when the flux on the primary winding 2 is distributed between the control core 24 and the working core 25, the flux connection between the primary 2 and the secondary 3 winding will be slight and very little energy transfer takes place between primary 2 and secondary 3 winding.

When the switch is on, i.e. when the reluctance in the control core 24 is very low (μr = 10-50) and approaching the reluctance of an air coil, we will have a very good flux connection between primary 2 and secondary 3 winding and transfer of energy.

An important application of the invention will thus be as a frequency converter with reluctance-controlled switches and a DC-AC or AC-DC converter by employing the reluctance-controlled switch in traditional frequency converter connections and rectifier connections.

A frequency converter variant may be envisaged realised by adding bits of sinus voltages from each phase in a three-phase system, each connected to a

separate reluctance-controlled core which in turn is connected to one or more adding cores which are magnetically connected to the reluctance-controlled cores through a common winding through the adding cores and the reluctance-controlled cores. Parts of sinus voltages can then be connected from the reluctance-controlled cores into the adding core and a voltage with a different frequency is generated.

A DC-AC converter may be realised by connecting a DC voltage to the main winding enclosing the working core, where this time the working core is also wound round a secondary winding where we can obtain a sinus voltage by changing the flux connection between working core and control core sinusoidally.

Fig. 66 illustrates the connection for a magnetic switch. This may, of course, also act as an adjustable transformer.

Figures 67 and 67a illustrate an example of a three-phase design. All the other three-phase rectifier connectors are, of course, also feasible. By means of connection to a diode bridge or individual diodes to the respective outlets in a 12-pulse connector, an adjustable rectifier is obtained.

In the application as an adjustable transformer, it must be emphasised that the size of the reluctance-controlled core is determined by the range of adjustment which is required for the transformer, (0-100% or 80-110%) for the voltage.

Figure 67b illustrates the use of the device according to the invention as a connector in a frequency converter for converting input frequency to randomly selected output frequency and intended for operation of an asynchronous motor, for adding parts of the phase voltage generated from a 6 or 12-pulse transformer to each motor phase (figure 67b).

Fig. 68 illustrates the device used as a switch in a UFC (unrestricted frequency changer with forced commutation).

Fig. 69 illustrates a circuit comprising 6 devices 28-33 according to the invention. The devices 28-33 are employed as frequency converters where the period of the voltages generated is composed of parts of the fundamental frequency. This works by "letting through" only the positive half-periods or parts of the half-periods of a sinus voltage in order to make the positive new

half-period in the new sinus voltage, and subsequently the negative half-periods or parts of the negative half-periods in order thereby to make the negative half-periods in the new sinus voltage. In this way a sinus voltage is generated with a frequency from 10% to 100% of the fundamental frequency. This converter also acts as a soft start since the voltage on the output is regulated via the reluctance control of the connection between the primary and the secondary winding.

In fig. 69, if the first half-period is allowed through connector no. 28 (main winding 2), the current through the secondary winding (main winding 3) in the same connector will commutate to the secondary winding (main winding 3) in connector no. 29, and on from 29 to 28, etc.

Fig. 70 illustrates the use of the device according to the invention as a DC to AC converter. Here the main winding 2 in the connector is excited by a DC voltage U1 which establishes a field H1 (B1) both in the control core 24 and in the main core 25 (these are not shown in the figure). The number of turns N1, N2, N3 and the area of iron are designed in such a manner that none of the cores are in saturation in steady state. In the event of a control signal (i.e. excitation of the control winding 4) into the control core 24, the flux B2 (H2) therein will be transferred to the main core 25 and a change in the flux B1 (H1) in this core 25 will induce a voltage in the secondary winding (main winding 3). By having a sinusoidal control current I2, a sinusoidal voltage will be able to be generated on the secondary side (main winding 3), with the same frequency as the control voltage U1.

Figure 70b illustrates the use of the invention as a converter with a change of reluctance.

Figure 71 illustrates a use of the device according to the invention as an AC-DC converter. The same control principle is used here as that explained above in the description of a frequency converter in fig. 69. Figure 71b illustrates a diagram of the time of the device's input and output voltage.

As mentioned previously, the voltage connector according to the invention is substantially without movable parts for the absorption of electrical voltage between a generator and a load. The function of the connector is to be able to control the voltage between the generator and the load from 0-100% by means of a small control current. A second function will be purely as a

voltage switch. A further function could be forming and transforming of a voltage curve.

The new technology according to the invention will be capable of being used for upgrading existing diode rectifiers, where there is a need for regulation. In connection with 12-pulse or 24-pulse rectifier systems, it will be possible to balance voltages in the system in a simple manner while having controllable rectification from 0-100%.

With regard to the magnetic materials involved in the invention, these will be chosen on the basis of a cost/benefit function. The costs will be linked to several parameters such as availability on the market, produceability for the various solutions selected, and price. The benefit functions are based on which electro-technical function the material requires to have, including material type and magnetic properties. Magnetic properties considered to be important include hysteresis loss, saturation flux level, permeability, magnetisation capacity in the two main directions of the material and magnetostriction. The electrical units frequency, voltage and power to the energy sources and users involved in the invention will be determining for the choice of material. Suitable materials include the following:

a) Iron - silicon steel: produced as a strip of a thickness approximately 0.1mm-0.3mm and width from 10mm to 1100mm and rolled up into coils. Perhaps the most preferred for large cores on account of price and already developed production technology. For use at low frequencies.

b) Iron - nickel alloys (permalloys) and/or iron - cobalt alloys (permendur) produced as a strip rolled up into coils. These are alloys with special magnetic properties with subgroups where very special properties have been cultivated.

c) Amorphous alloys, Metglas: produced as a strip of a thickness of approximately 20µm - 50µm, width from 4mm to 200mm and rolled up into coils. Very high permeability, very low loss, can be made with almost 0 magnetostriction. Exists in a countless number of variants, iron-based, cobalt-based, etc. Fantastic properties but high price.

d) Soft ferrites: Sintered in special forms developed for the converter industry. Used at high frequencies due to small loss. Low flux density. Low loss. Restrictions on physically realisable size.

e) Compressed powder cores: Compressed iron powder alloy in special shapes developed for special applications. Low permeability, maximum approximately 400-600 to-day. Low loss, but high flux density. Can be produced in very complicated shapes.

All sintered and press-moulded cores can implement the topologies which are relevant in connection with the invention without the need for special magnetic field connectors, since the actual shape is made in such a way that closed magnetic field paths are obtained for the relevant fields.

If cores are made based on rolled sheet metal, they will have to be supplemented by one or more magnetic field connectors.

PATENT CLAIMS

1. A magnetically influenced current or voltage regulator, characterized in that it comprises:

- a body (1) which is composed of a magnetisable material and provides a closed, magnetic circuit,
- at least one first electrical conductor (8) wound round the body (1) along at least a part of the closed circuit for at least one turn which forms a first main winding (2),
- at least one second electrical conductor (9) wound around the body (1) along at least a part of the closed circuit for at least one turn which forms a second main winding or control winding (4),
- where the winding axis (A2) for the turn or turns in the main winding (2) is at right angles to the winding axis (A4) for the turn or turns in the control winding (4) with the object of providing orthogonal magnetic fields (H1, B1 and H2, B2 respectively) in the body (1) and thereby controlling the behaviour of the magnetisable material relative to the field (H1, B1) in the main winding (2) by means of the field (H2, B2) in the control winding (4).

2. A device as indicated in claim 1, characterized in that

- the axis (A2) for the turn(s) in the main winding (2) is parallel to or coincident with the body's (1) longitudinal direction (A1), while the turn(s) in the control winding (4) extend substantially along the magnetisable body (1), and the axis (A4) for the control winding (4) is therefore at right angles to the body's (1) longitudinal direction (A1).

3. A device as indicated in claim 1, characterized in that

- the axis (A4) for the turn(s) in the control winding (4) is parallel to or coincident with the body's (1) longitudinal direction (A1), while the turn(s) in the main winding (2) extend substantially along the magnetisable body (1), and the axis (A2) for the main winding (2) is therefore at right angles to the body's (1) longitudinal direction (A1).

4. A device as indicated in one of the preceding claims, characterized in that it comprises one third electrical conductor (27) wound

round the body (1) along at least a part of the closed circuit for at least one turn which forms a third main winding (3), where the winding axis (A3) for the turn or turns in the third main winding (3) coincides with or is parallel to the winding axis (A2) for the turn or turns in the first main winding (2), thus providing a transformer effect between the first and the third main windings (2 and 3 respectively) when at least one of them is excited.

5. A device as indicated in one of the claims 1-3, characterized in that it comprises one third electrical conductor (27) wound round the body (1) along at least a part of the closed circuit for at least one turn which forms a third main winding (3), where the winding axis (A3) for the turn or turns in the third main winding (3) coincides with or is parallel to the winding axis (A4) for the turn or turns in the first control winding (4), thus providing a transformer effect between the third main winding and the control winding (3 and 4 respectively) when at least one of them is excited.

6. A magnetically influenced current or voltage regulator, characterized by

- a first body (6) and a second body (7) each of which is composed of a magnetisable material which provides a magnetic circuit, the said bodies (6, 7) being juxtaposed,
- at least one first electrical conductor (8) wound along at least a part of the closed circuit for at least one turn which forms a first main winding (2),
- at least one second electrical conductor (9) wound around at least a part of the first and/or second body (6 and 7 respectively) for at least one turn which forms a second main winding or control winding (4', 4"),
- where the winding axis (A2) for the turn or turns in the main winding (2) is at right angles to the winding axis (A4) for the turn or turns in the control winding (4) with the object of providing orthogonal magnetic fields (H1, B1 and H2, B2 respectively) in the body (1) and thereby controlling the behaviour of the magnetisable material relative to the field (H1, B1) in the main winding (2) by means of the field (H2, B2) in the control winding (4).

7. A magnetically influenced current or voltage regulator, characterized by

- a first body (6) and a second body (7) each of which is composed of a magnetisable material and a first magnetic field connector (10) and a second magnetic field connector (11) which together with the bodies (6, 7) provide a

closed, magnetic circuit, the said bodies (6, 7) being juxtaposed,

- at least one first electrical conductor (8) wound around at least a part of the first and/or the second body (6 and 7 respectively) for at least one turn which forms a first main winding (2),
- at least one second electrical conductor (9) wound along at least a part of the closed circuit for at least one turn which forms a second main winding or control winding (4),
- where the winding axis (A2) for the turn or turns in the main winding (2) is at right angles to the winding axis (A4) for the turn or turns in the control winding (4) with the object of providing orthogonal magnetic fields (H1, B1 and H2, B2 respectively) in the body (1) and thereby controlling the behaviour of the magnetisable material relative to the field (H1, B1) in the main winding (2) by means of the field (H2, B2) in the control winding (4).

8. A device as indicated in claim 6 or 7, characterized in that it further comprises magnetic field connectors (10, 11) which together with the bodies form the magnetic circuit.

9. A device as indicated in claims 6, 7 or 8, characterized in that it comprises one third electrical conductor (27) wound for one turn which forms a third main winding (3), where the winding axis (A3) for the turn or turns in the third main winding (3) coincides with or is parallel to the winding axis (A2) for the turn or turns in the first main winding (2), thus providing a transformer effect between the first and the third main windings (2 and 3 respectively) when at least one of them is excited.

10. A device as indicated in one of the claims 6, 7 or 8, characterized in that it comprises one third electrical conductor (27) wound for at least one turn which forms a third main winding (3), where the winding axis (A3) for the turn or turns in the third main winding (3) coincides with or is parallel to the winding axis (A4) for the turn or turns in the control winding (4), thus providing a transformer effect between the third main winding and the control winding (3 and 4 respectively) when at least one of them is excited.

11. A device according to claim 6, 7, 8, 9 or 10, characterized in that the first and the second body (6 and 7 respectively) are

tubular in shape, thus enabling the first conductor (8) or the second conductor (9) to extend through the first and the second body (6 and 7 respectively, claim 6 and claim 7 respectively), and the magnetic field connectors (10, 11) comprise apertures (12) for the conductors (8, 9).

12. A device according to claim 11,
characterized in that the magnetic field connectors (10, 11) each comprise a gap (13) to facilitate the insertion of the first or the second conductor (8 and 9 respectively) and to interrupt the magnetic field path of the magnetic field H1 (B1) from the conductor (8 and 9 respectively).

13. A device according to claim 11,
characterized in that it is equipped with an insulating film (15) placed between the end surfaces of the tubes (6, 7) and the magnetic field connectors (10, 11).

14. A device according to claim 11,
characterized in that each tube (6, 7) comprises two or more core parts (16, 16', 16").

15. A device according to claim 14,
characterized in that it comprises an insulating layer (17) arranged between the core parts (16, 16', 16").

16. A device according to one of the claims 6-15,
characterized in that the tubes (6, 7) have circular, square, rectangular, triangular or hexagonal cross sections.

17. A magnetically influenced current or voltage regulator,
characterized by

- a first, external tubular body (20) and a second, internal tubular body (21) each of which is composed of a magnetisable material and provides a magnetic circuit, the said bodies (20, 21) being concentric relative to each other and thus having a common axis (A1)
- at least one first electrical conductor (8) wound round the tubular bodies (20, 21) for at least one turn which forms a first main winding (2),
- at least one second electrical conductor (9) provided in the gap (22) between the bodies (20, 21) and wound around the body's common axis (A1) for at least one turn which forms a second main winding or control winding

(4),

- where the winding axis (A2) for the turn or turns in the main winding (2) is at right angles to the winding axis (A4) for the turn or turns in the control winding (4) with the object of providing orthogonal magnetic fields (H1, B1 and H2, B2 respectively) in the body (1) and thereby controlling the behaviour of the magnetisable material relative to the field (H1, B1) in the main winding (2) by means of the field (H2, B2) in the control winding (4).

18. A magnetically influenced current or voltage regulator, characterized by

- a first, external tubular body (20) and a second, internal tubular body (21) each of which is composed of a magnetisable material together with a first magnetic field connector (10) and a second magnetic field connector (11) which together with the bodies (20, 21) provide a closed, magnetic circuit, the said bodies (20, 21) being concentric relative to each other and thus having a common axis (A1)
- at least one first electrical conductor (8) provided in the gap (22) between the bodies (20, 21) and wound around the body's common axis (A1) for at least one turn which forms a first main winding (2),
- at least one second electrical conductor (9) wound round the tubular bodies (20, 21) for at least one turn which forms a second main winding or control winding (4),

where the winding axis (A2) for the turn or turns in the main winding (2) is at right angles to the winding axis (A4) for the turn or turns in the control winding (4) with the object of providing orthogonal magnetic fields (H1, B1 and H2, B2 respectively) in the body (1) and thereby controlling the behaviour of the magnetisable material relative to the field (H1, B1) in the main winding (2) by means of the field (H2, B2) in the control winding (4).

19. A device according to claims 17 or 18, characterized in that it comprises a first magnetic field connector (10) and a second magnetic field connector (11) which together with the bodies (20, 21) provide a closed magnetic circuit.

20. A device according to claim 17, 18 or 19, characterized in that it comprises one third electrical conductor (27) wound for one turn which forms a third main winding (3), where the winding axis (A3) for the turn or turns in the third main winding (3) coincides with or is

parallel to the winding axis (A2) for the turn or turns in the first main winding (2), thus providing a transformer effect between the first and the third main windings (2 and 3 respectively) when at least one of them is excited.

21. A device according to claim 17, 18 or 19, characterized in that it comprises one third electrical conductor (27) wound for at least one turn which forms a third main winding (3), where the winding axis (A3) for the turn or turns in the third main winding (3) coincides with or is parallel to the winding axis (A4) for the turn or turns in the control winding (4), thus providing a transformer effect between the third main winding and the control winding (3 and 4 respectively) when at least one of them is excited.

22. A magnetically influenced current or voltage regulator, characterized by

- a first, external tubular body (20) and a second, internal tubular body (21) each of which is composed of a magnetisable material which provides a closed magnetic circuit or internal core (24),
- an additional tubular body which provides an external core (25) which is mounted on the outside of the first, external tubular body (20), where the bodies (20, 21, 25) are concentric relative to each other and thus have a common axis (A1)
- at least one first electrical conductor (8) wound round the tubular bodies (20, 21, 25) for at least one turn which forms a first main winding (2),
- at least one second electrical conductor (9) mounted in the gap (22) between the first (20) and the second body (21) and wound around the bodies' common axis (A1) for at least one turn which forms a second main winding or control winding (4),
- where the winding axis (A2) for the turn or turns in the main winding (2) is at right angles to the winding axis (A4) for the turn or turns in the control winding (4) with the object of providing orthogonal magnetic fields (H1, B1 and H2, B2 respectively) in the body (1) and thereby controlling the behaviour of the magnetisable material relative to the field (H1, B1) in the main winding (2) by means of the field (H2, B2) in the control winding (4).

23. A magnetically influenced current or voltage regulator, characterized by

- a first, external tubular body (20) and a second, internal tubular body (21) each of which is composed of a magnetisable material which forms a closed, magnetic circuit or internal core (24),
- an additional tubular body which provides an external core (25) which is mounted on the outside of the first, external tubular body (20), where the bodies (20, 21, 25) are concentric relative to each other and thus have a common axis (A1)
- at least one first electrical conductor (8) mounted in the gap (22) between the first (20) and the second body (21) and wound round the bodies' common axis (A1) for at least one turn which forms a second main winding or control winding (4),
- at least one second electrical conductor (9) wound around the tubular bodies (20, 21) for at least one turn which forms a second main winding or control winding (4),
- where the winding axis (A2) for the turn or turns in the main winding (2) is at right angles to the winding axis (A4) for the turn or turns in the control winding (4) with the object of providing orthogonal magnetic fields (H1, B1 and H2, B2 respectively) in the body (1) and thereby controlling the behaviour of the magnetisable material relative to the field (H1, B1) in the main winding (2) by means of the field (H2, B2) in the control winding (4).

24. A device according to claim 22 or 23, characterized in that it comprises a first magnetic field connector (10) and a second magnetic field connector (11) which together with the bodies (20, 21) provide the closed magnetic circuit.

25. A device according to claim 22, 23 or 24, characterized in that it comprises one third electrical conductor (27) wound around the external core (25) for one turn which forms a third main winding (3), where the winding axis (A3) for the turn or turns in the third main winding (3) coincides with or is parallel to the winding axis (A2) for the turn or turns in the first main winding (2), thus providing a transformer effect between the first and the third main windings (2 and 3 respectively) when at least one of them is excited.

26. A device according to claim 22, 23 or 24, characterized in that it comprises one third electrical conductor (27) wound around the external core (25) for at least one turn which forms a third main

winding (3), where the winding axis (A3) for the turn or turns in the third main winding (3) coincides with or is parallel to the winding axis (A4) for the turn or turns in the control winding (4), thus providing a transformer effect between the third main winding and the control winding (3 and 4 respectively) when at least one of them is excited.

27. A device according to one of the claims 22-26, characterized in that the external core (25) consists of several annular parts (25', 25", etc.) and that the first and/or the third main winding (2 and 3 respectively) form individual windings around each annular part.

28. A device according to one of the claims 22-26, characterized in that the external core (25) consists of several annular parts (25', 25", etc.) and that the control winding and/or the third main winding (4 and 3 respectively) form individual windings around each annular part.

29. The use of a device as indicated in one or more of the preceding claims 1-28 as a component in a frequency converter for converting input frequency to randomly selected output frequency (figure 69), preferably intended for operation of an asynchronous motor in a cycloconverter connection.

30. The use of a device as indicated in one or more of the preceding claims 1-28 as a connector in a frequency converter for converting input frequency to randomly selected output frequency and intended for operation of an asynchronous motor, for summation of parts of the phase voltage generated from a 6 or 12-pulse transformer to each motor phase (figure 67b).

31. The use of a device as indicated in one or more of the preceding claims 1-28 as a DC to AC converter which converts DC voltage/current to an AC voltage/current of a randomly selected output frequency, where the stored magnetic energy in a DC-fed first main winding (2) or primary winding's (2) inductance (L1) is varied by means of the orthogonal control field (B2, H2) which influences the inductance, thereby generating an AC voltage in the third main winding (3) or secondary winding in the voltage connector with frequency equal to the frequency of the flux variation/inductance variation (figure 70).

32. The use according to claim 31 where three such variable inductance voltage converters are interconnected in order to generate a three-phase

voltage with randomly selected output frequency which is connected to the said asynchronous machine.

33. The use of a device as indicated in one or more of claims 1-28 for converting AC voltage to DC voltage within the processing industry, where the device is used as a reluctance-controlled variable transformer where the output voltage is proportional to the reluctance alteration in a core which is magnetically connected in parallel or in series to an external or internal core with a separate secondary winding, and where three or more such reluctance-controlled transformers are connected to the known three-phase rectifier connections for 6 or 12-pulse rectifier connections for diode output stage (figs. 62 and 71 respectively).

34. The use of a device as indicated in one or more of claims 1-28 for use in rectifiers for converting AC voltage to DC voltage for use within the processing industry, where the device forms voltage connectors which are used as variable inductances in series with the primary windings on known transformer connections, and where three or more such transformers are connected to three-phase rectifier connections for 6 or 12-pulse rectifier connections for diode output stage (figure 62).

35. The use of the device as indicated in one or more of the preceding claims 1-28 for AC/DC or DC/AC converters for use in the field of switched power supply, for reduction of the size of the magnetic voltage converter, since the device forms a reluctance-controlled variable transformer where the output voltage is proportional to the reluctance change in a core which is magnetically connected in parallel or in series to an external or internal core with a separate secondary winding (figures 56, 63).

36. The use as indicated in claim 36, characterized in that filters in which inductance forms a part are provided with a variable inductance (figure 63).

37. The use of a device as indicated in one or more of the preceding claims 1-28 as a component in an adjustable voltage compensator in the high-voltage distributor network, where the device creates linear variable inductance (fig. 72).

38. The use of a device as indicated in one or more of the preceding claims 1-28 as a component in an adjustable reactive power compensator (VAR compensator), where the device creates linear variable inductance in connection with known filter circuits where at least one condenser is also included as an element, the device in the form of a reluctance-controlled transformer being employed as an element in a compensator connection where capacitance or inductance are automatically coupled in and adjusted to the extent required to compensate for the reactive power (figures 64 and 64b).

39. The use of a device as indicated in one or more of the preceding claims 1-28 in a system for reluctance-controlled direct conversion of an AC voltage to a DC voltage (figs. 71 and 71a).

40. The use of a device as indicated in one or more of the preceding claims 1-28 in a system for reluctance-controlled direction conversion of a DC voltage to an AC voltage (figs. 70 and 70a).

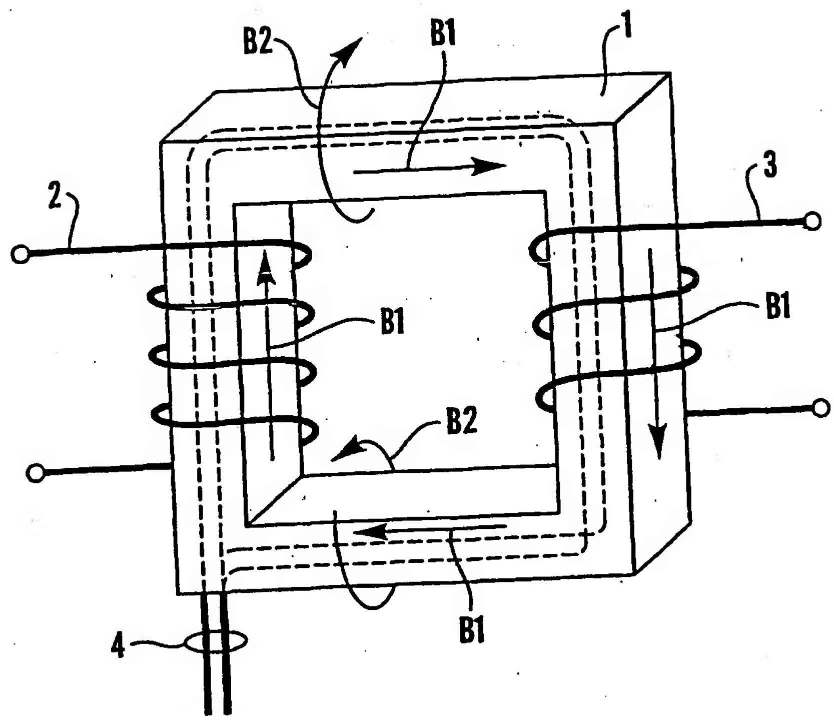


Fig. 1a

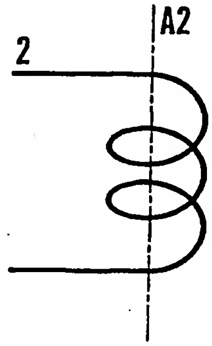


Fig. 1b

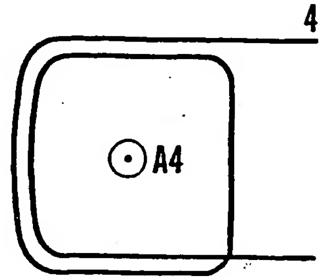


Fig. 1c

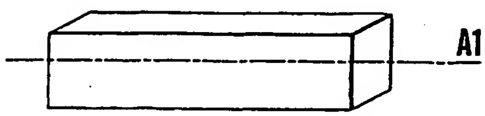


Fig. 1d

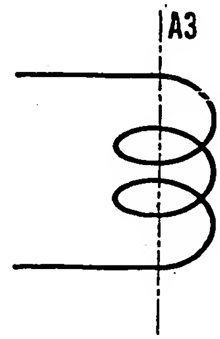


Fig. 1e

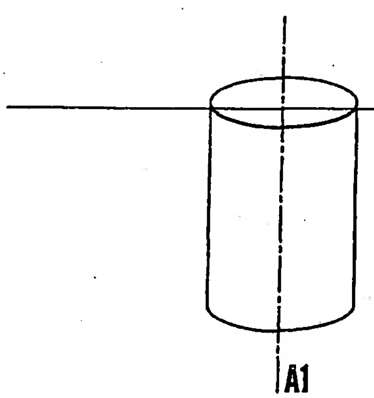


Fig. 1f

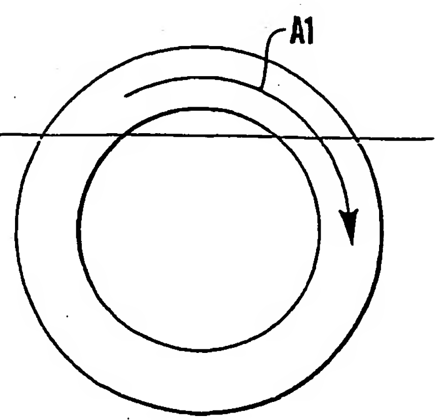


Fig. 1g

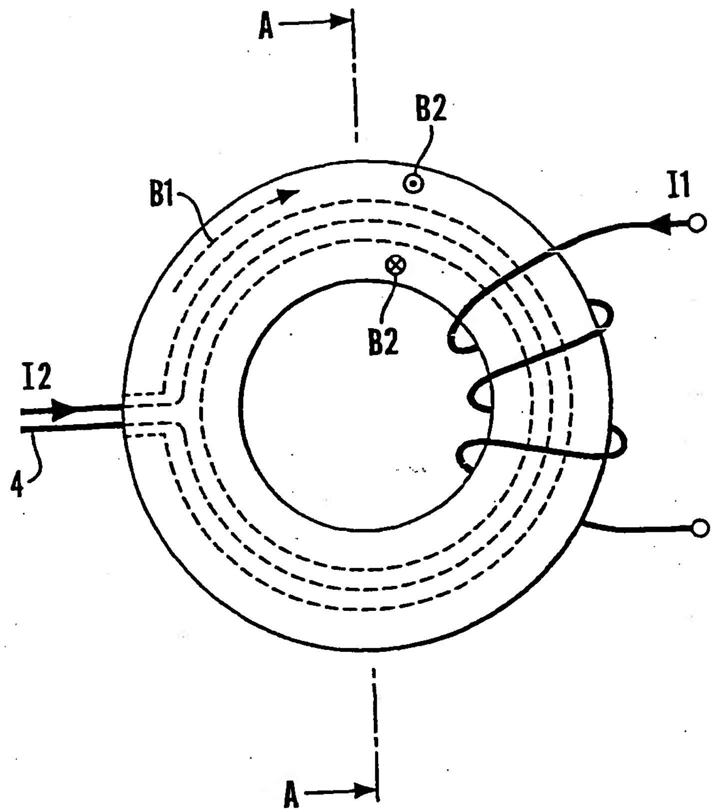
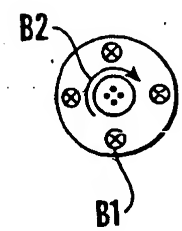


Fig.2a

Fig.2b



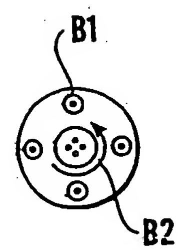


Fig.2c

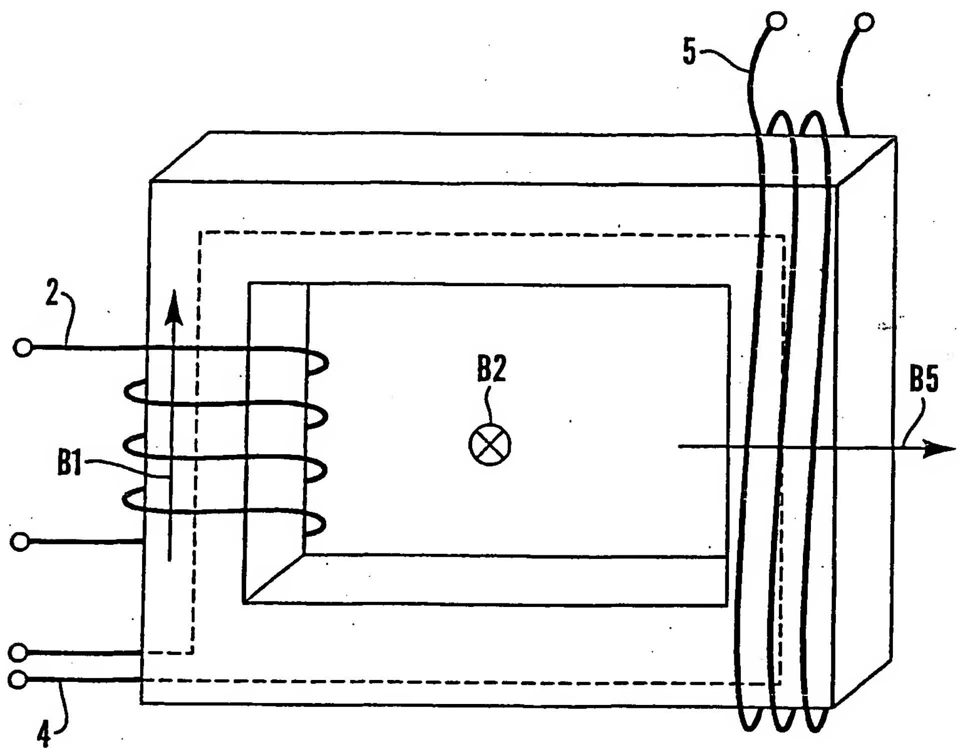


Fig.3

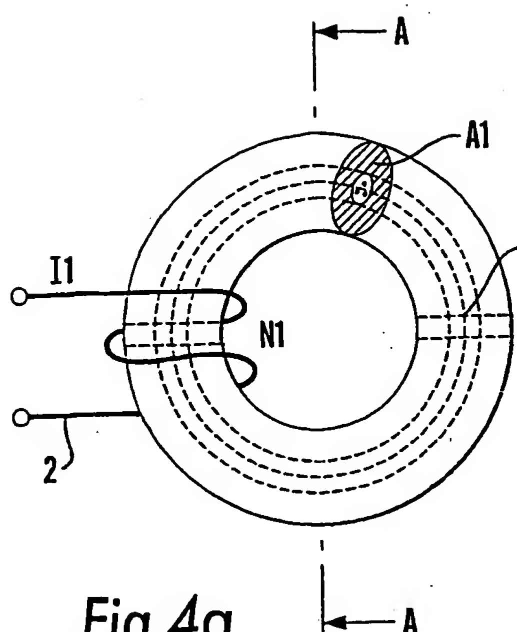


Fig.4a

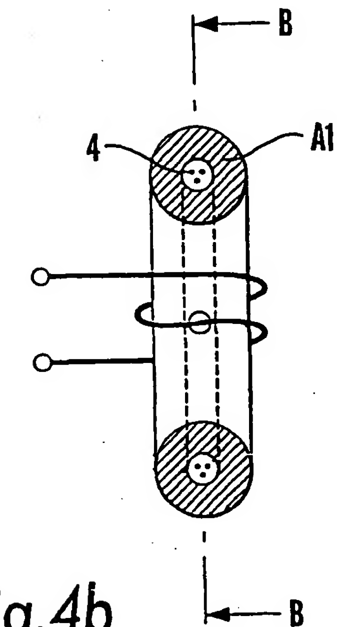


Fig.4b

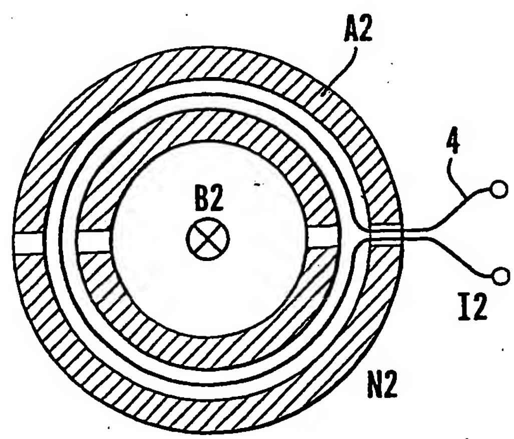


Fig.4c

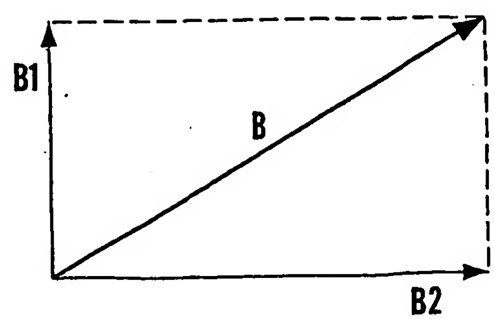


Fig.4d

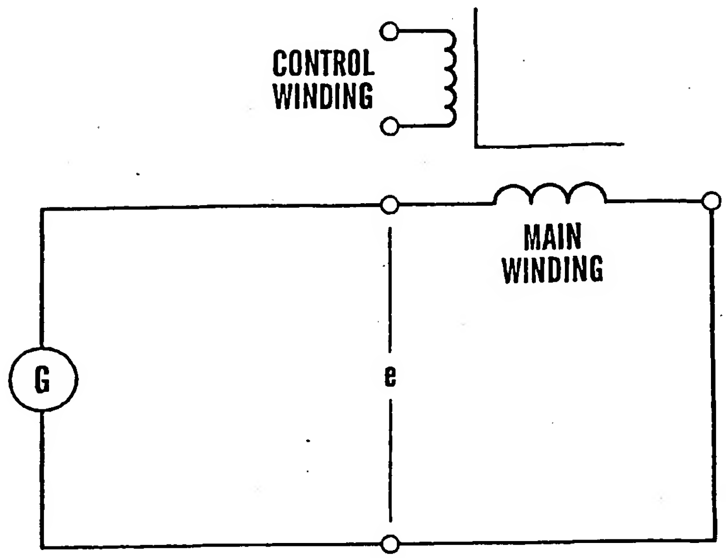


Fig.5a

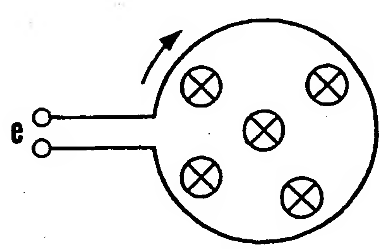


Fig.5b

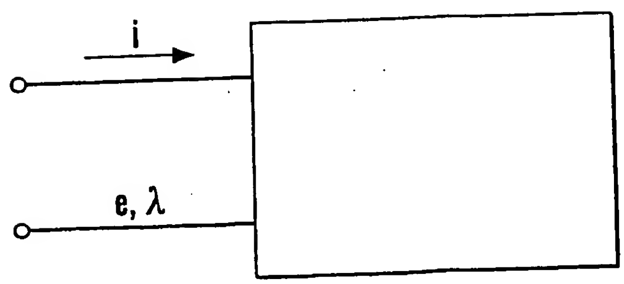


Fig.6

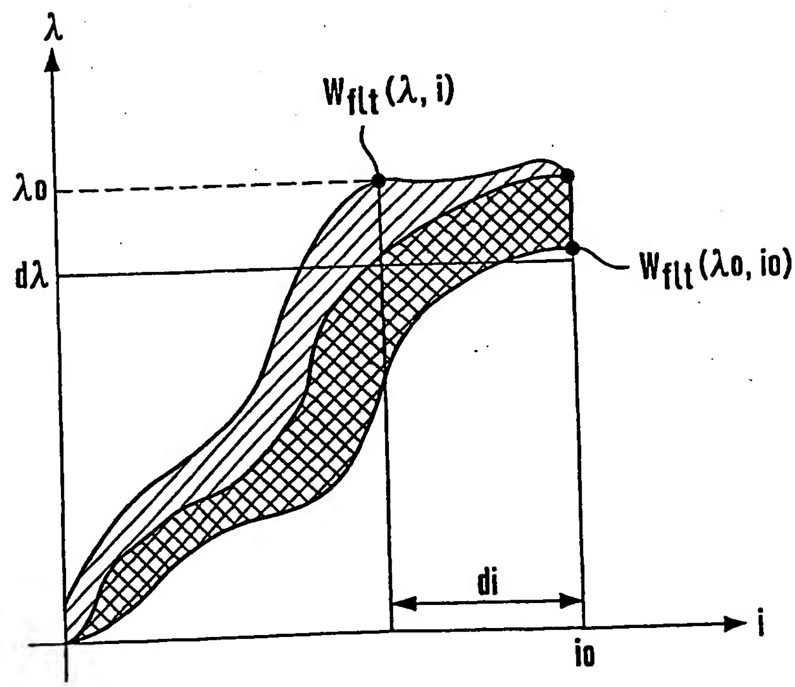


Fig.7

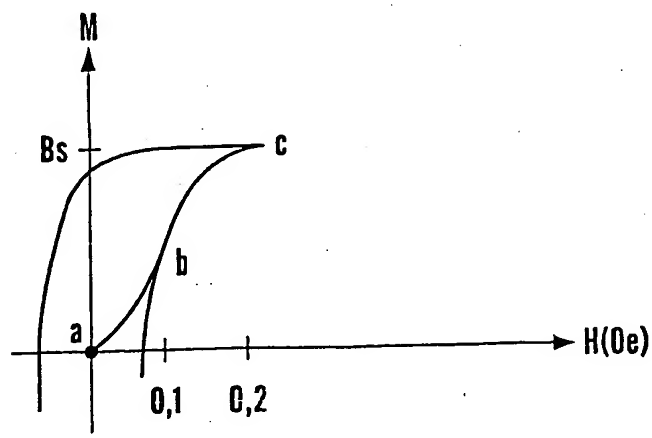


Fig.8a

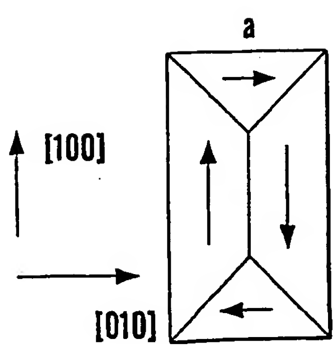


Fig.8b

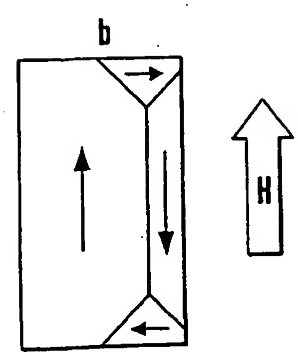


Fig.8b

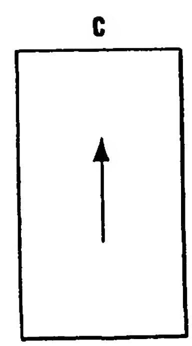


Fig.8d

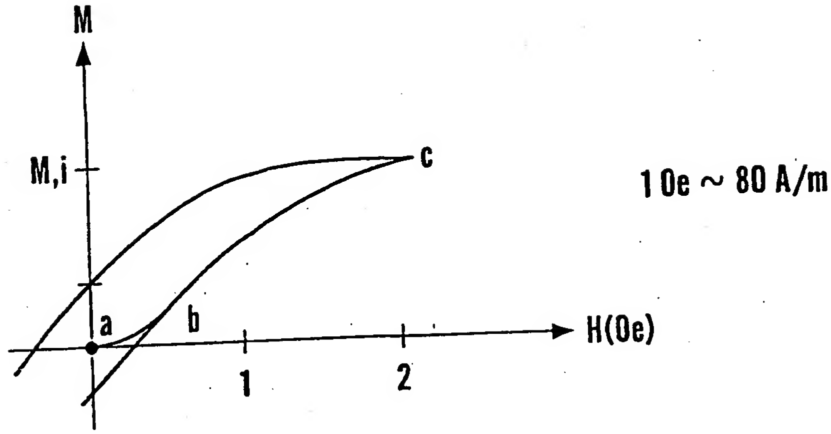


Fig.9a

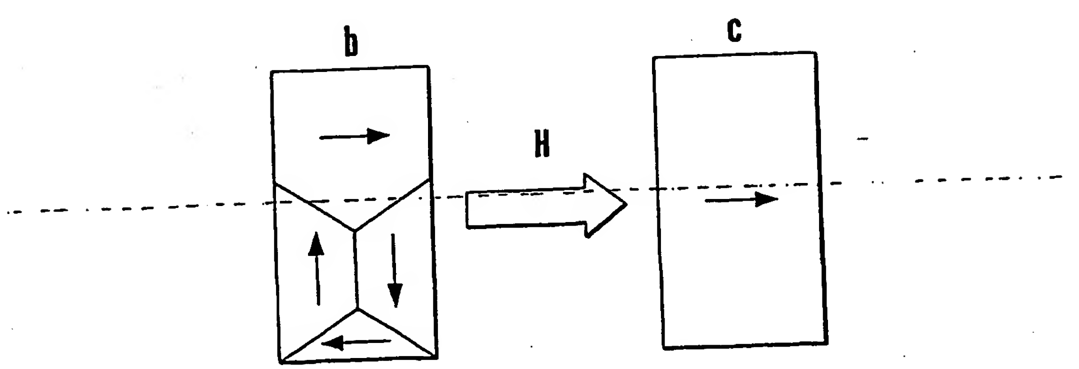


Fig.9b

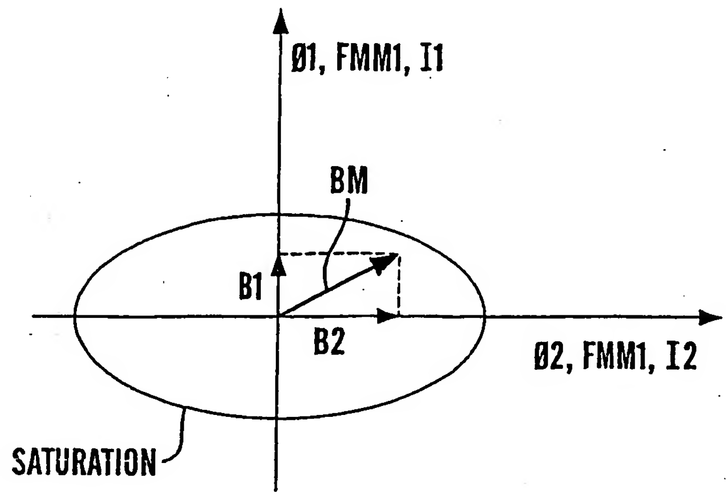


Fig. 10a

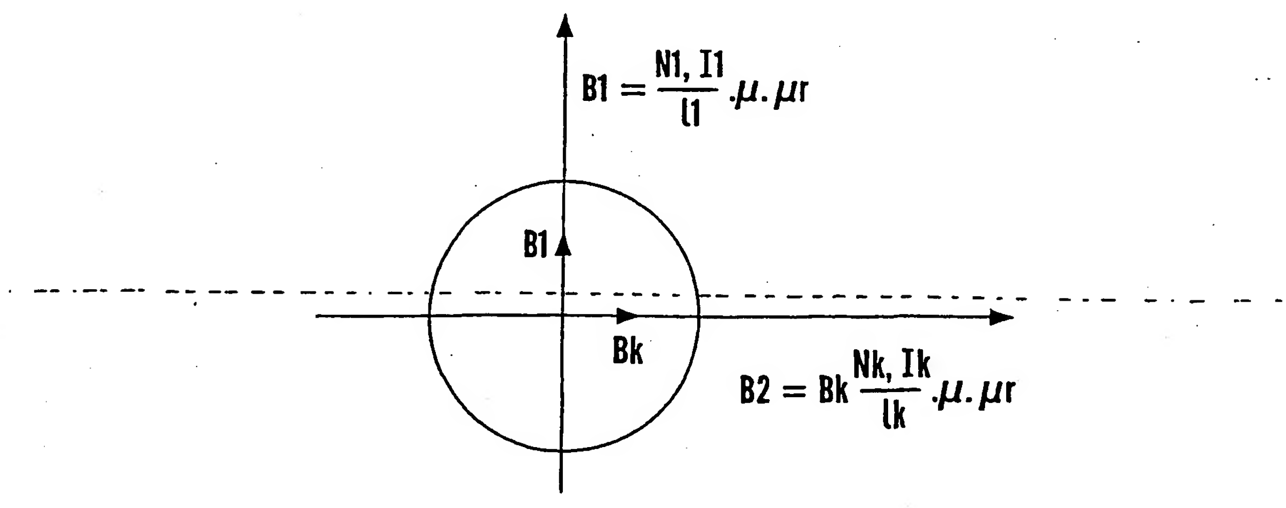


Fig. 10b

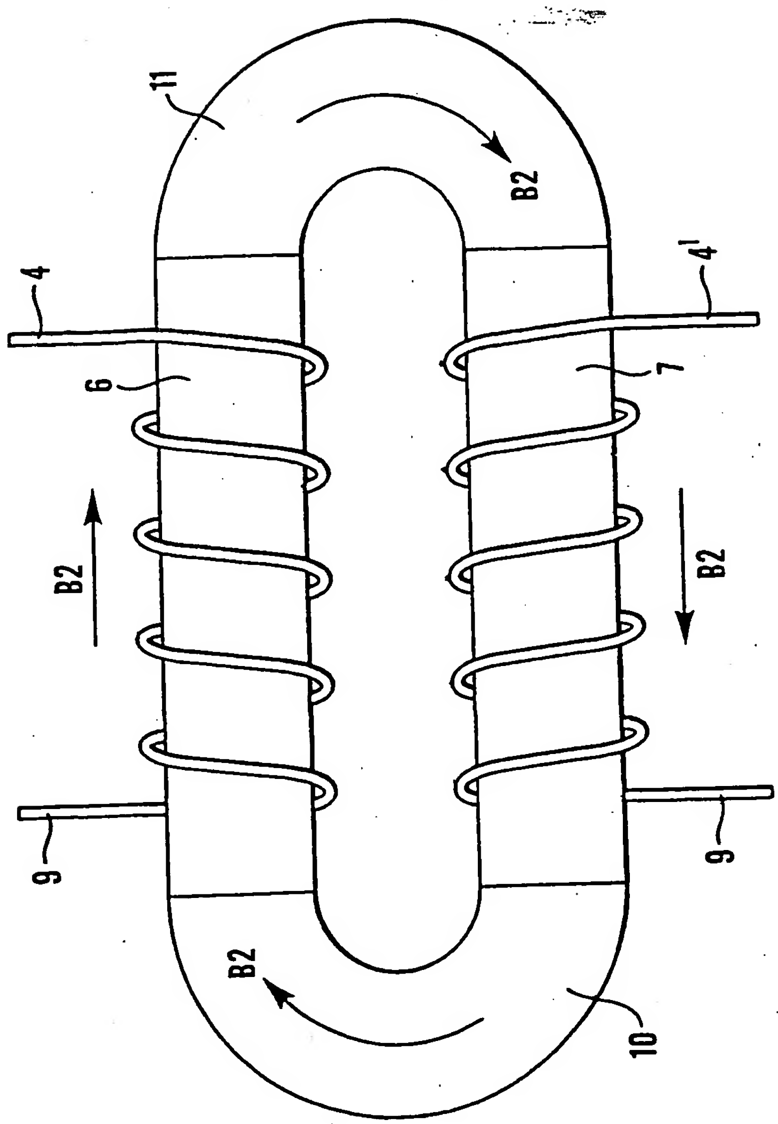


Fig.11e

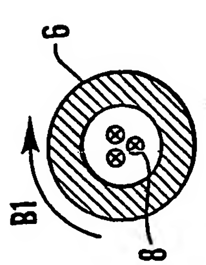


Fig.11a

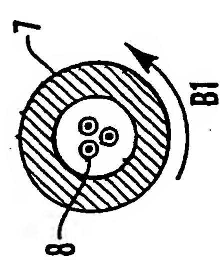


Fig.11b

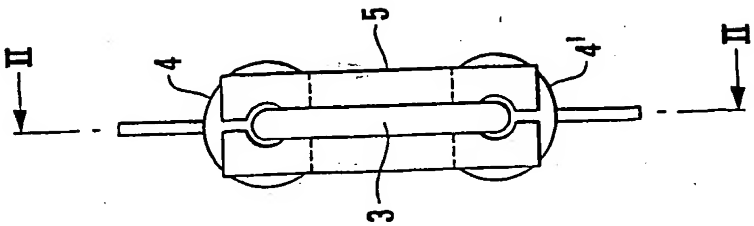


Fig. 12b

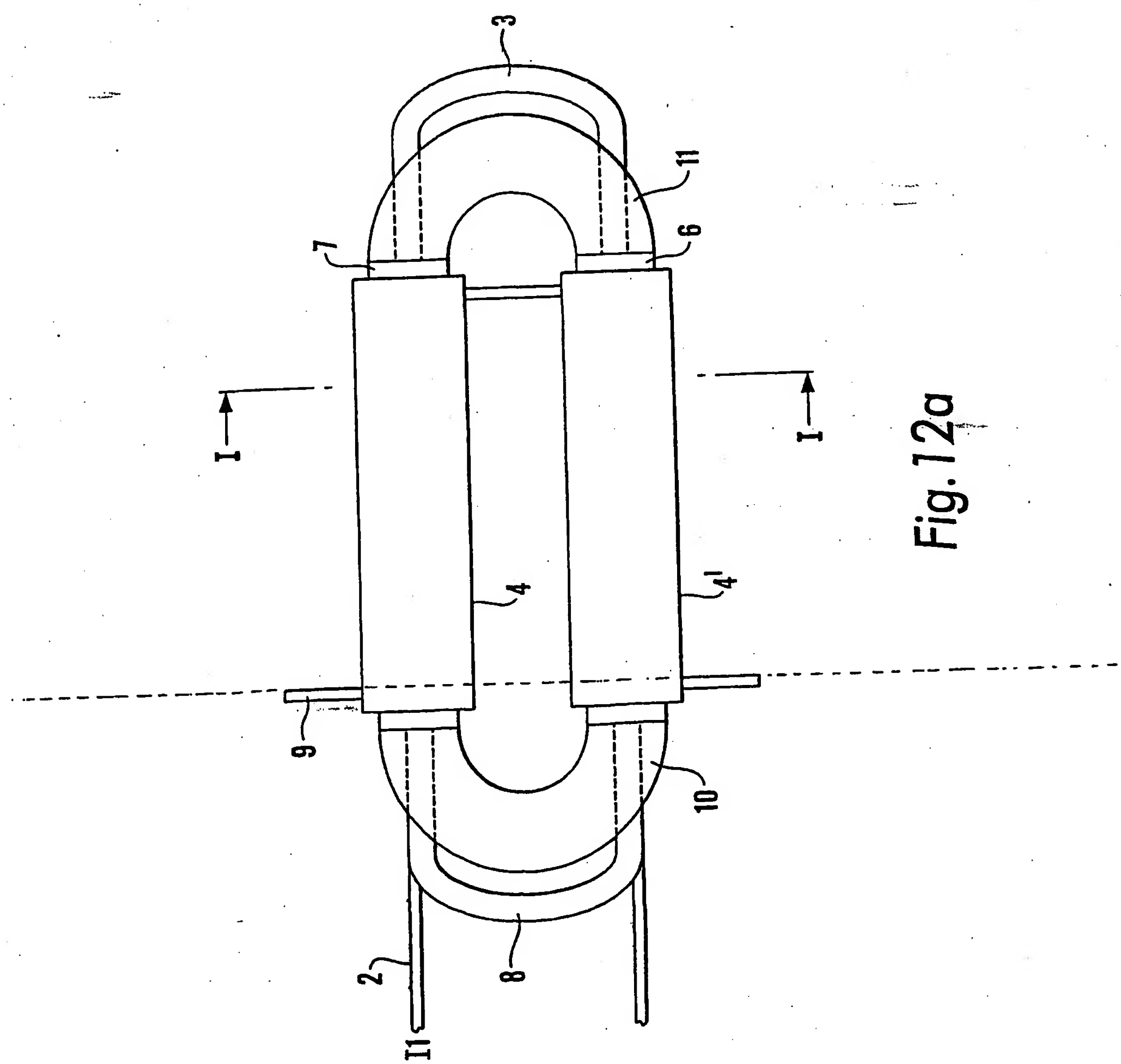


Fig. 12a

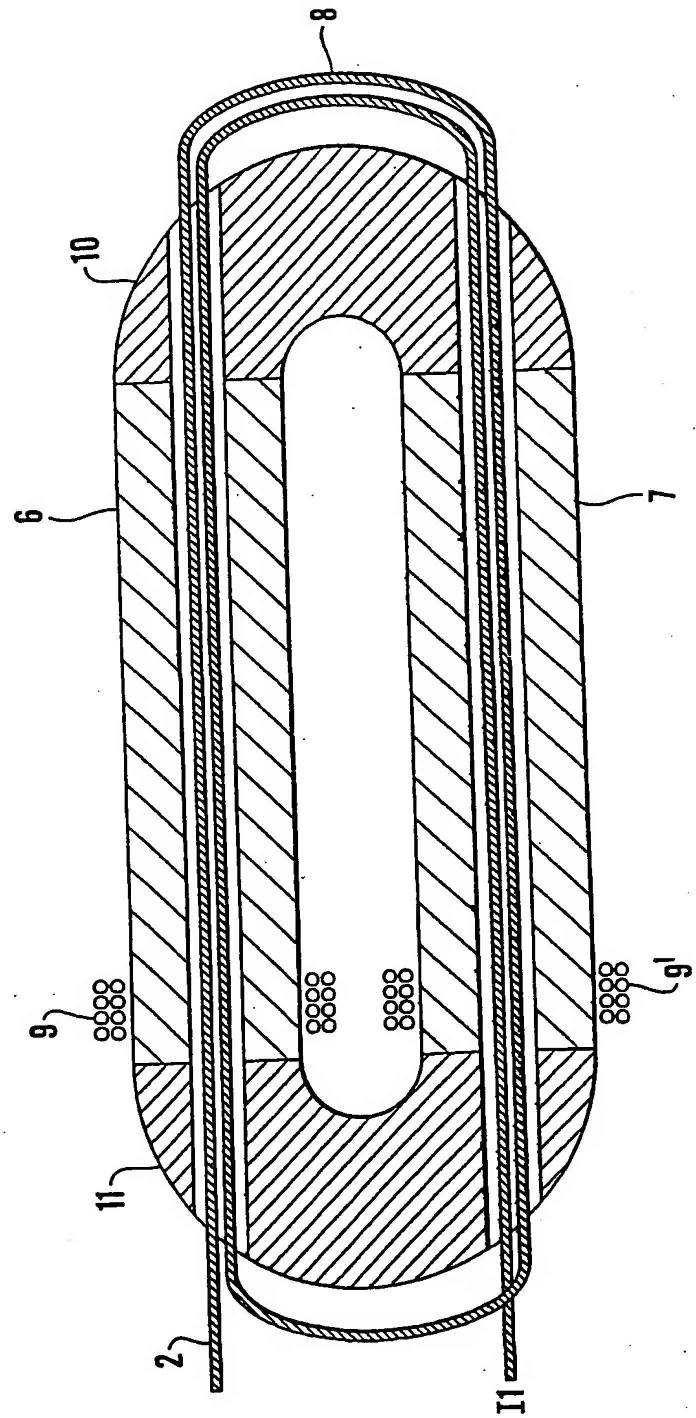


Fig. 13

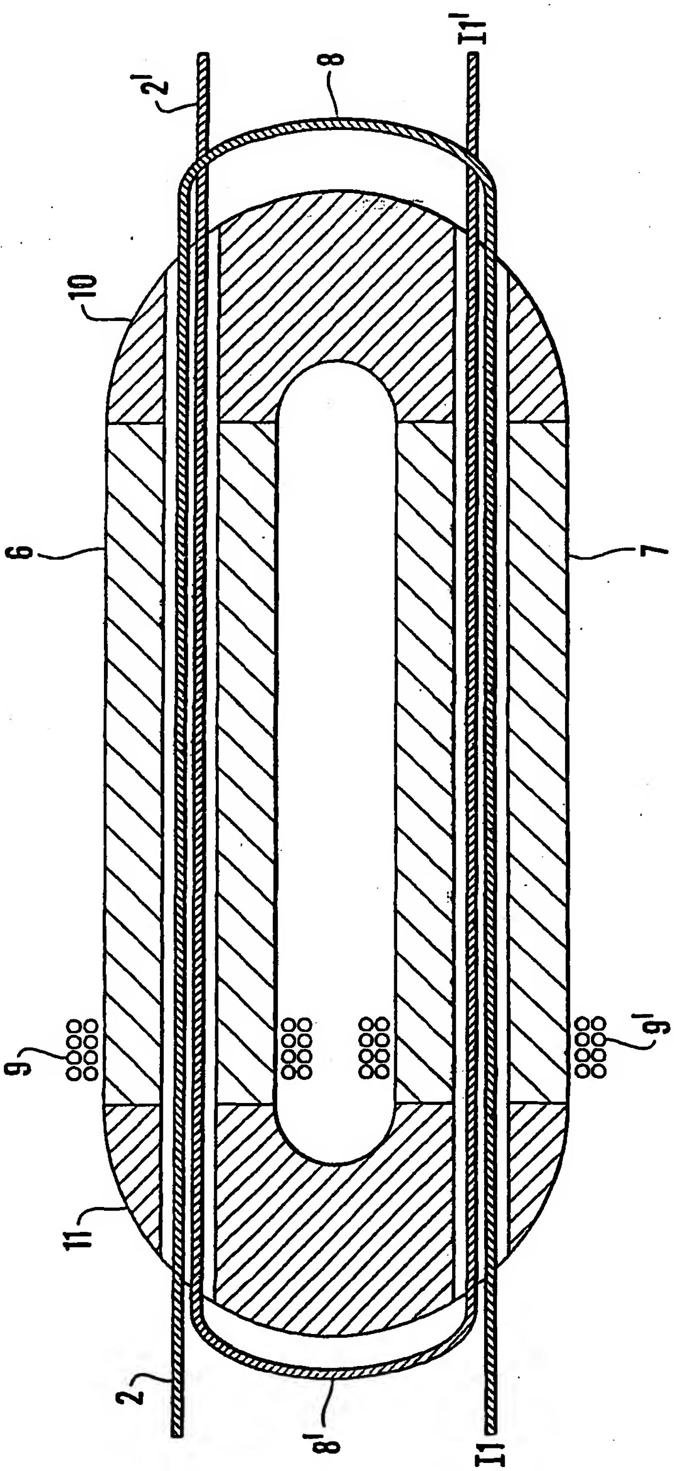


Fig. 14

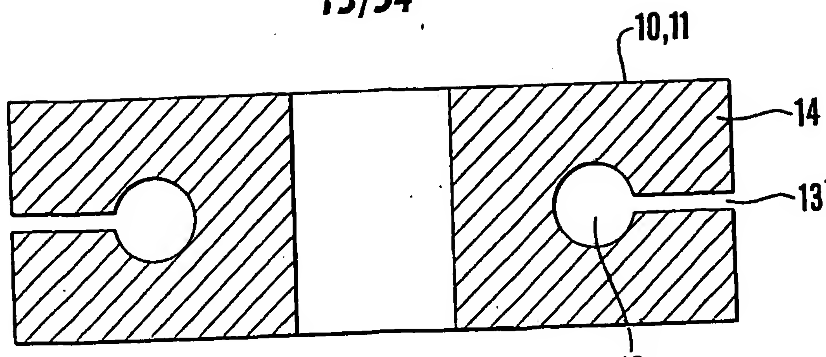


Fig. 15a

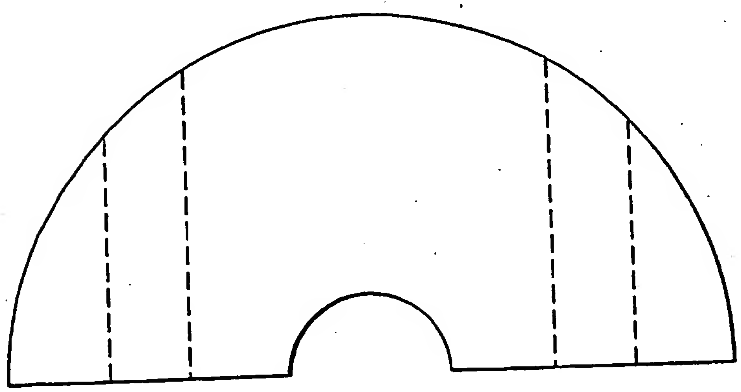


Fig. 15b

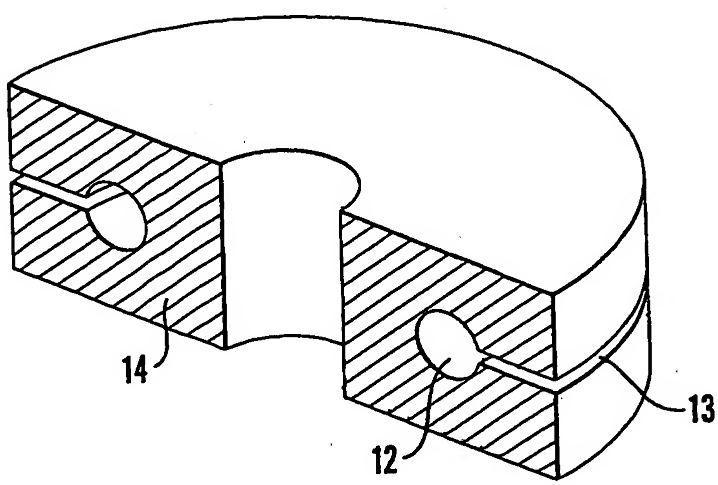


Fig. 15c

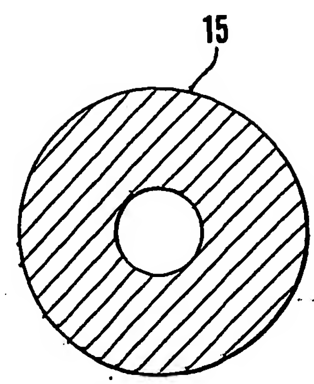


Fig. 16

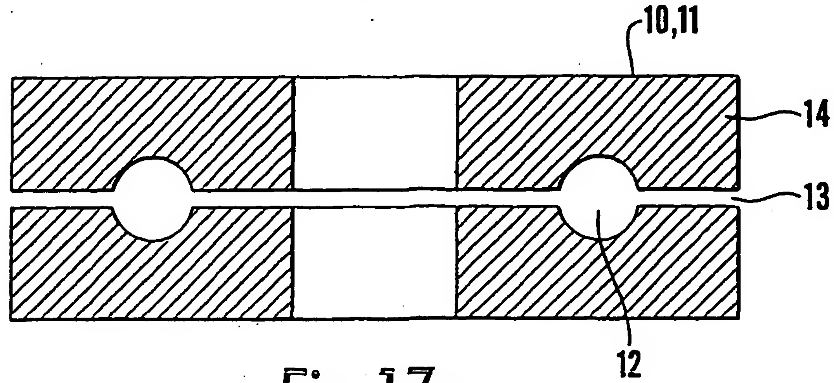


Fig. 17a

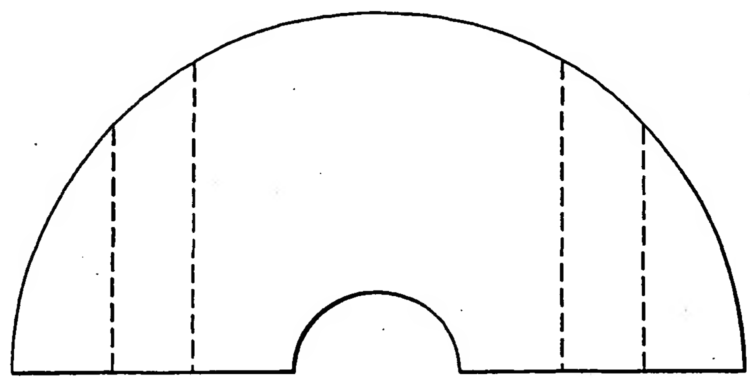


Fig. 17b

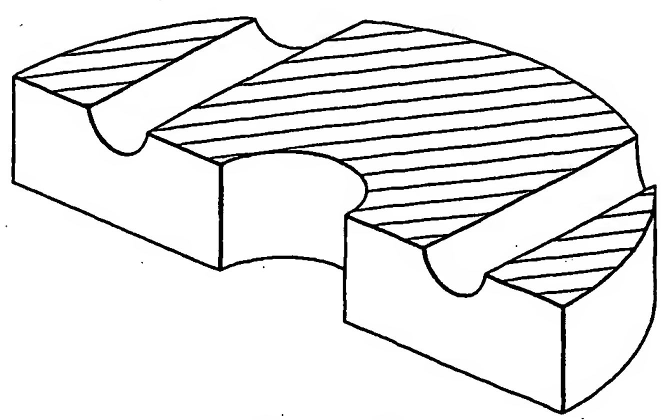


Fig. 17c

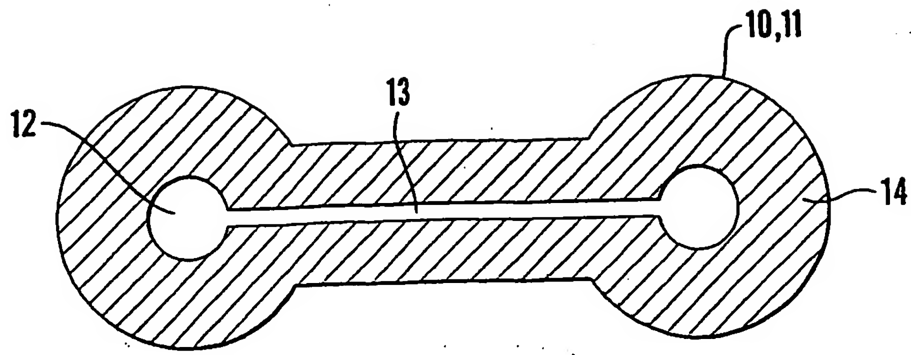


Fig. 18a

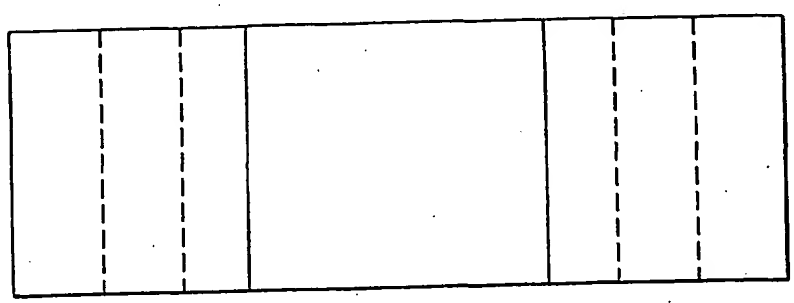


Fig. 18b

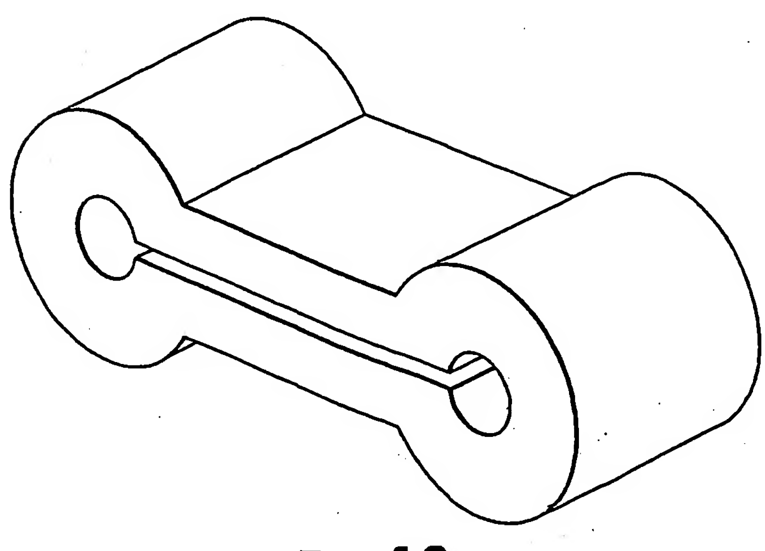


Fig. 18c

Fig.19

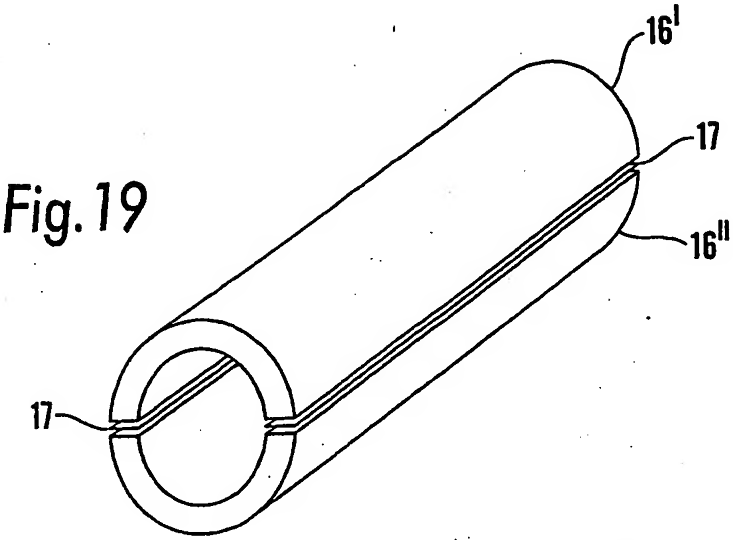


Fig.20

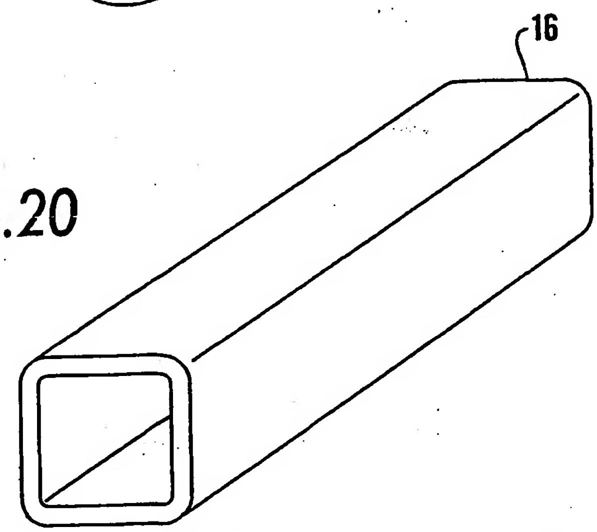


Fig.21

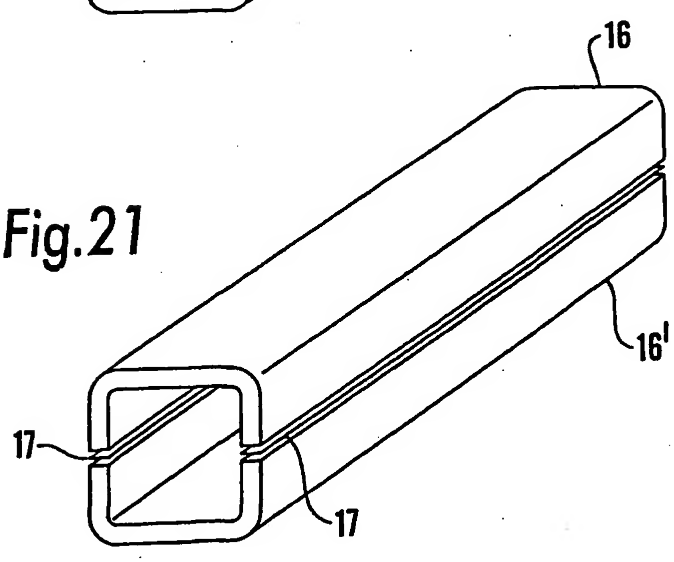


Fig.22

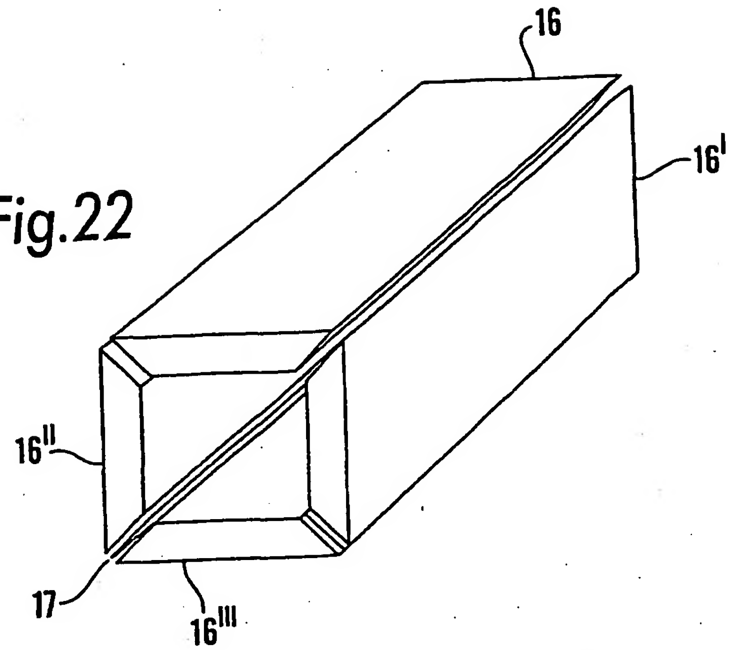


Fig.23

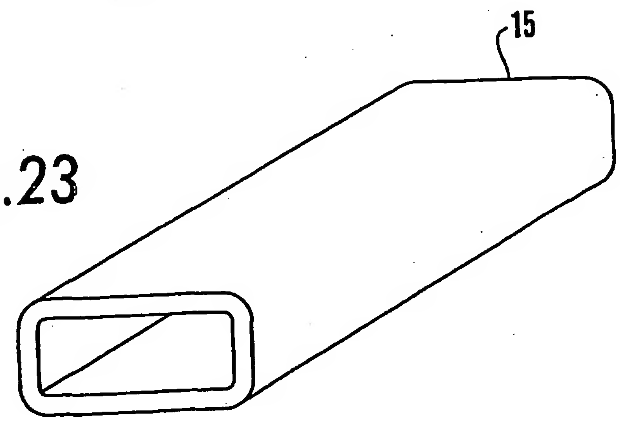


Fig.24

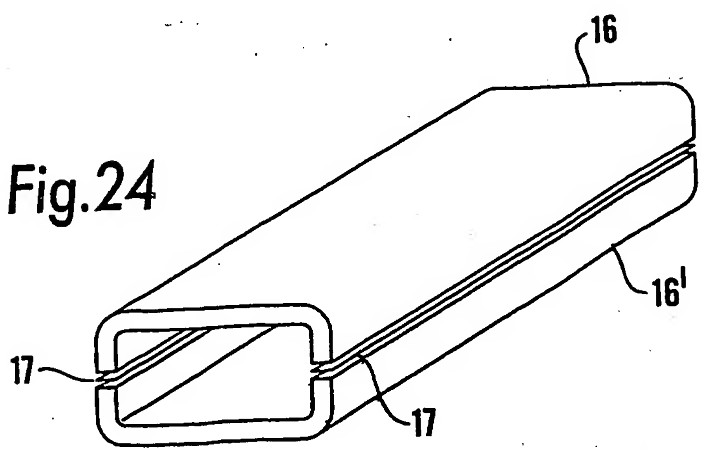


Fig.25

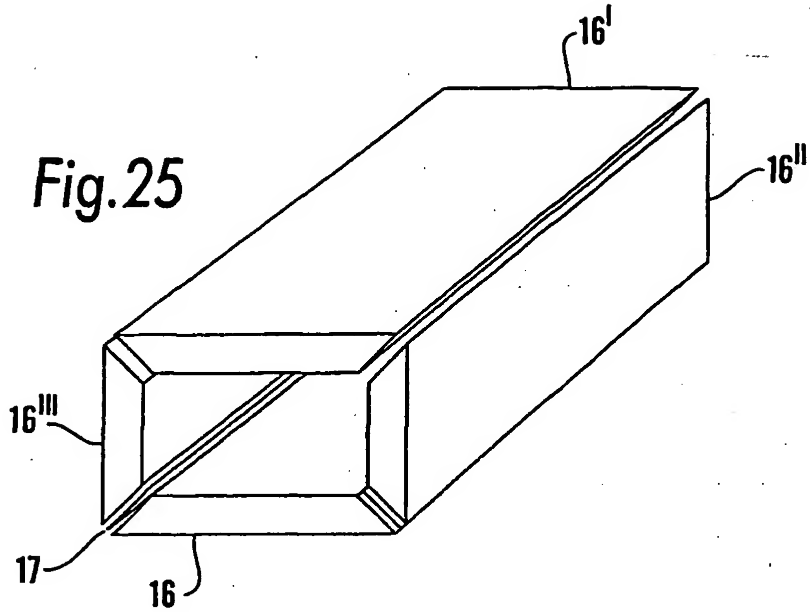


Fig.26

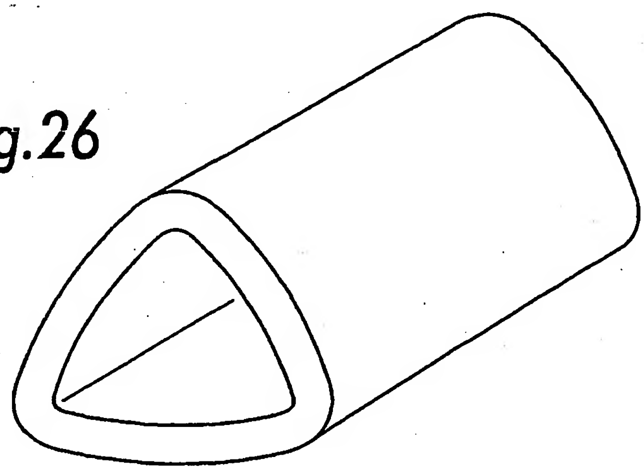


Fig.27

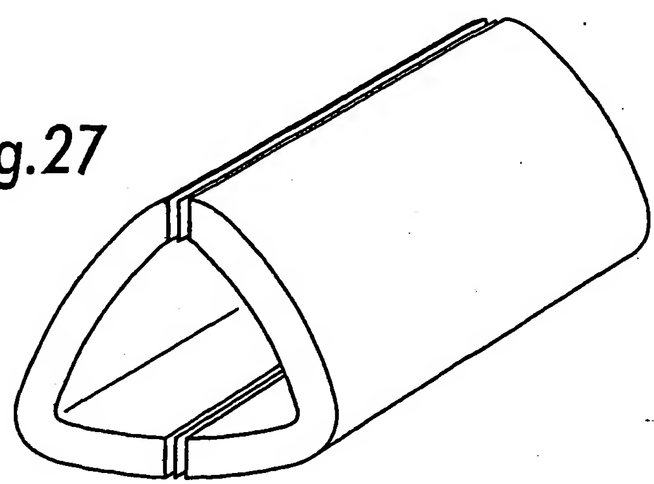


Fig.28

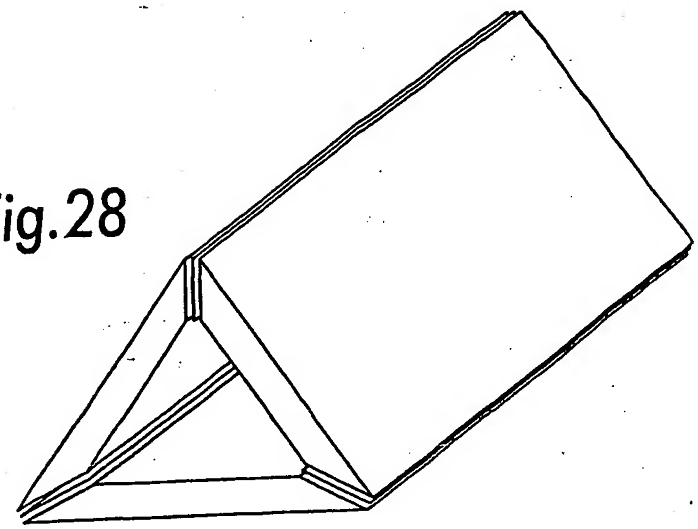


Fig.29

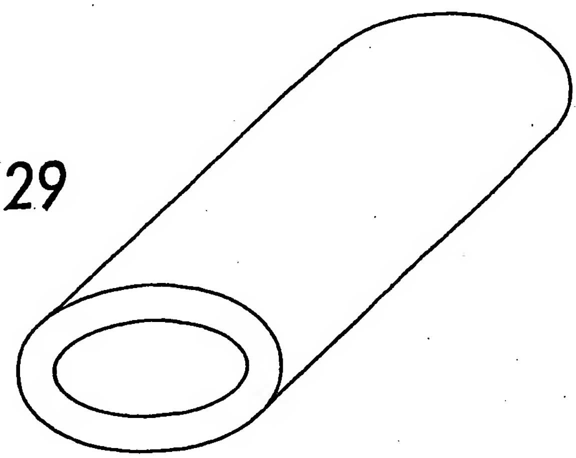


Fig.30

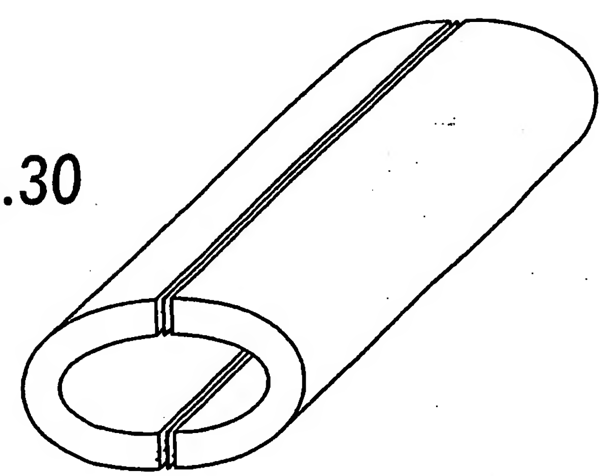


Fig.31

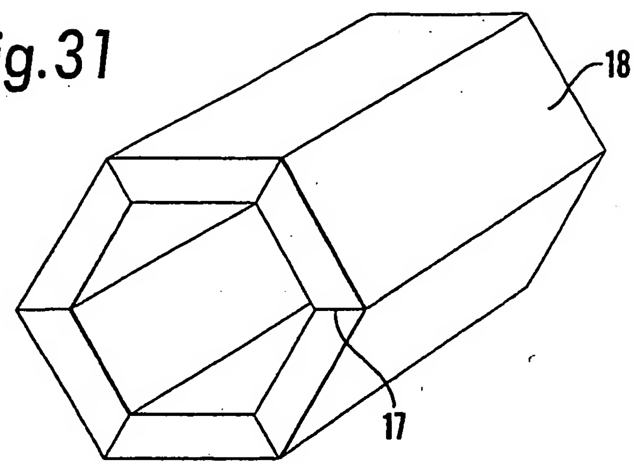
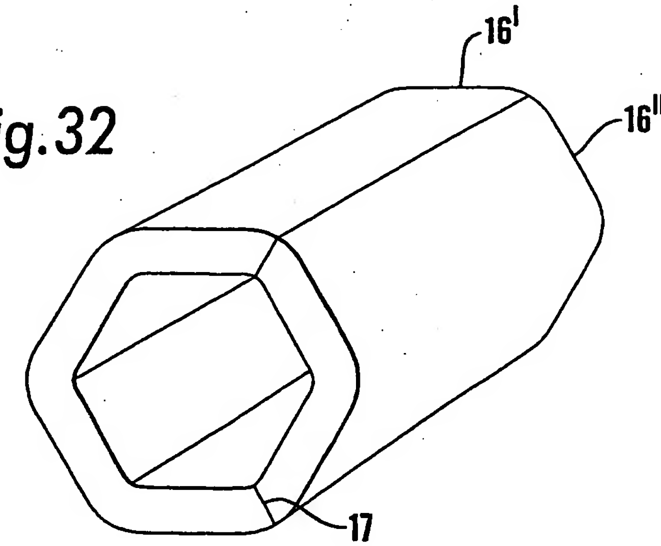


Fig.32



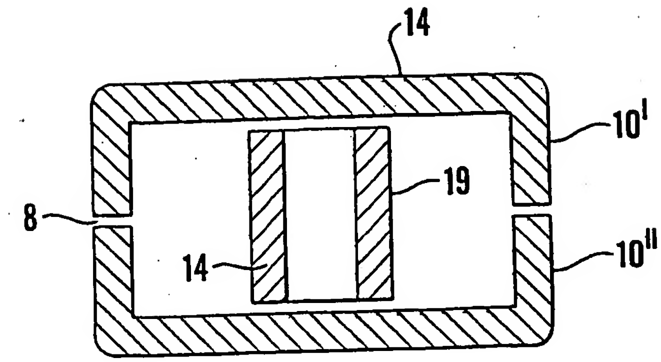


Fig.33a

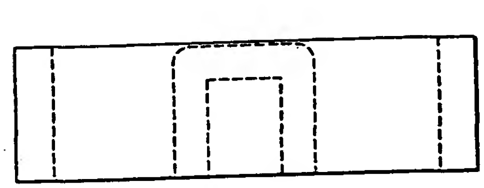


Fig.33b

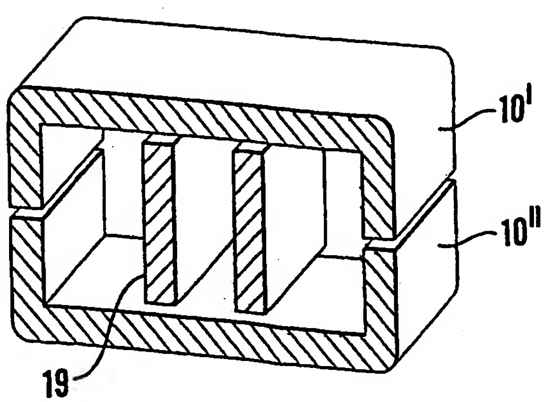


Fig.33c

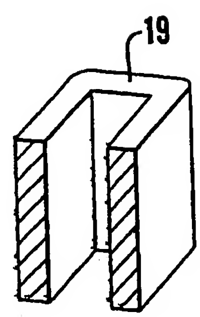


Fig.33d

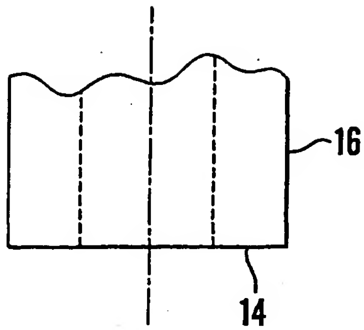


Fig.34

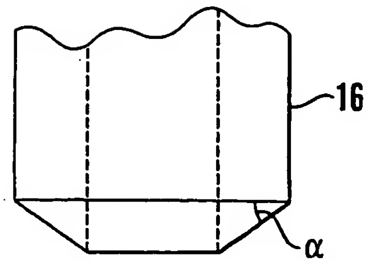


Fig.35

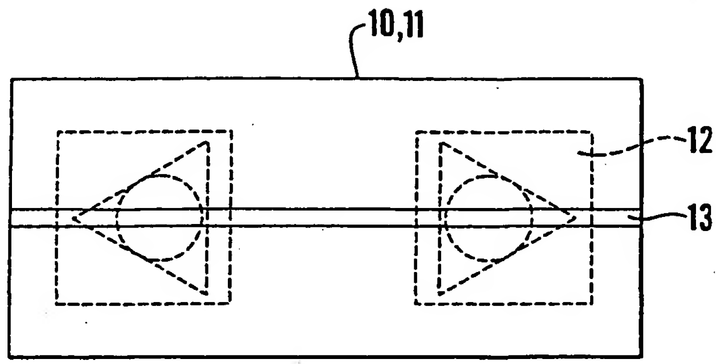


Fig.36

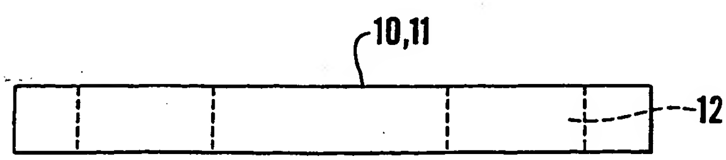


Fig.37

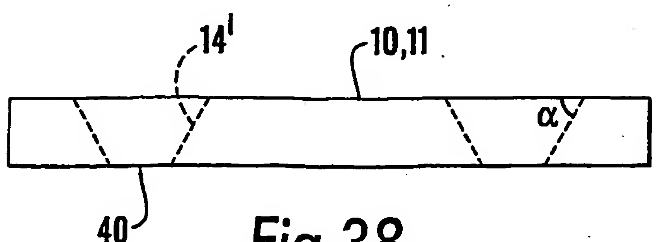


Fig.38

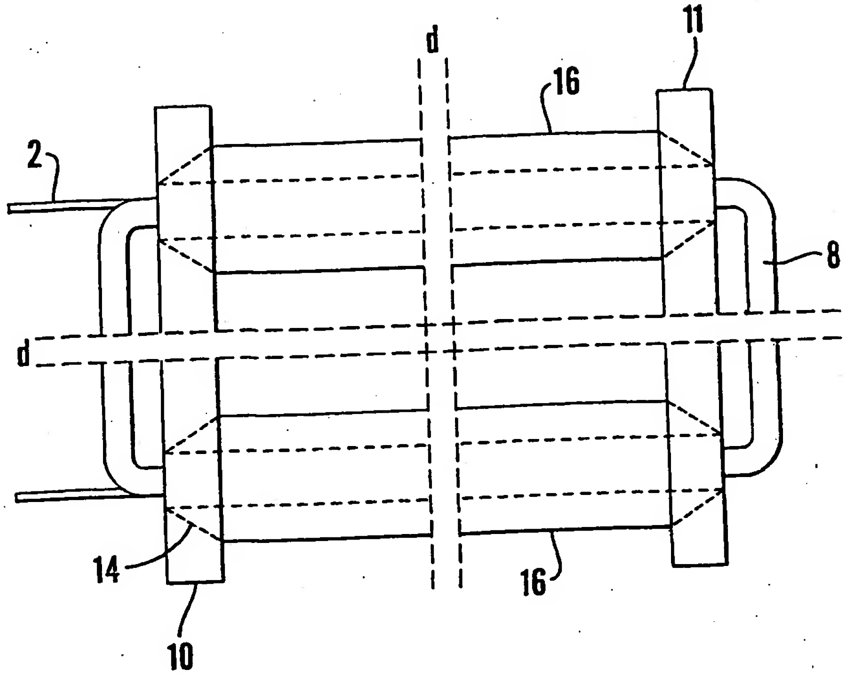


Fig.39a

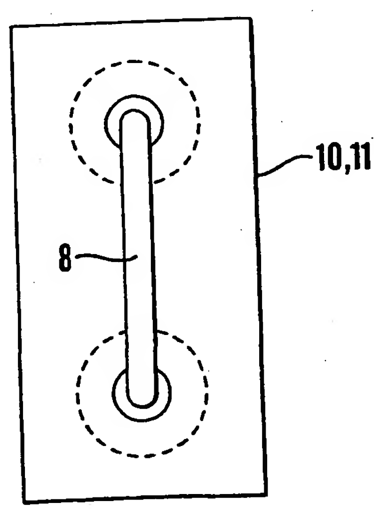


Fig.39b

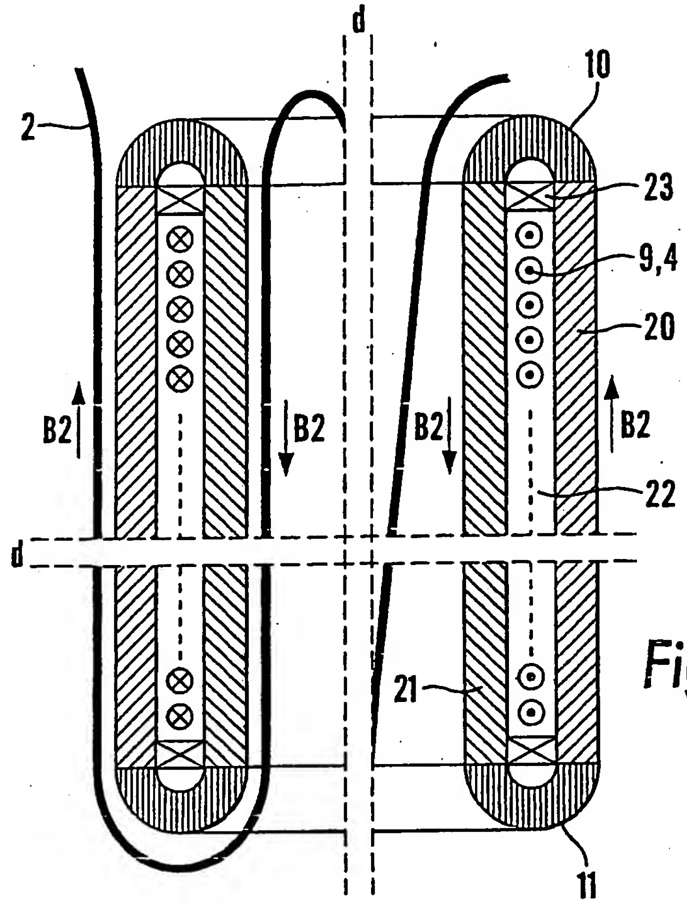


Fig.40a

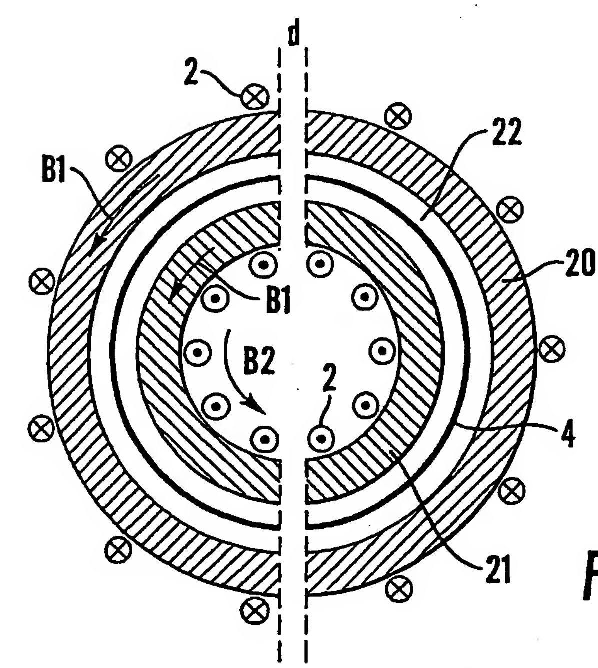


Fig.40b

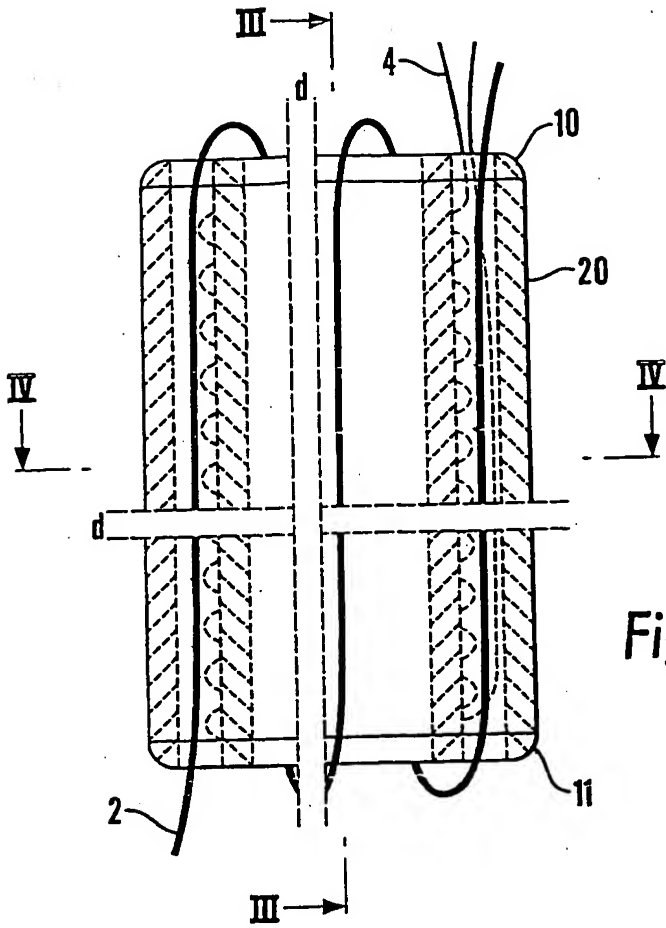


Fig.41a

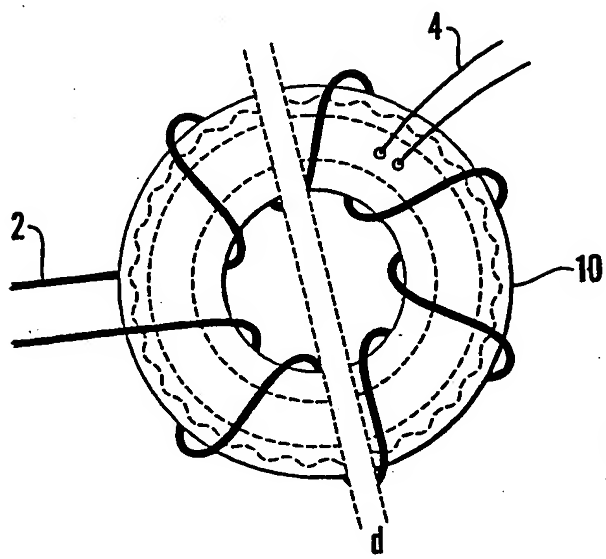


Fig.41b

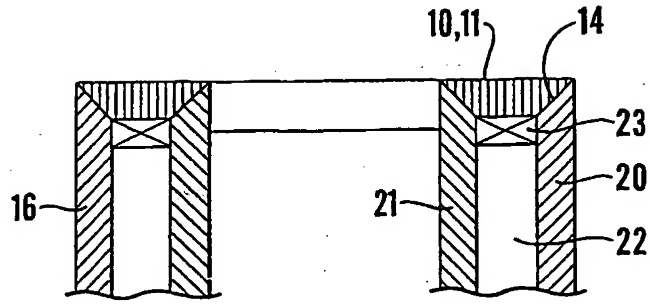


Fig.42a

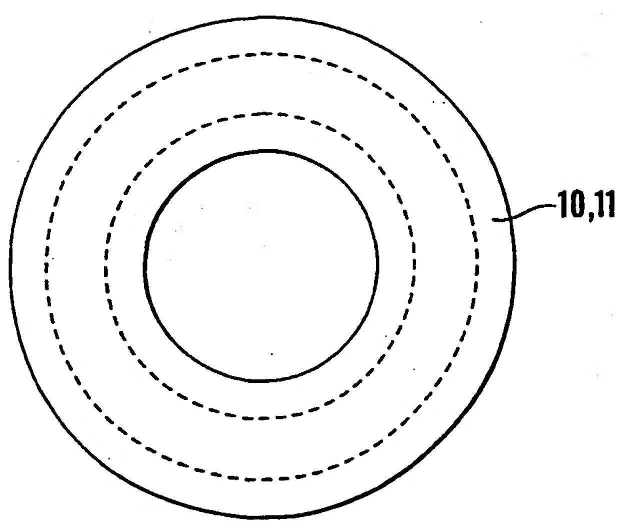


Fig.42b

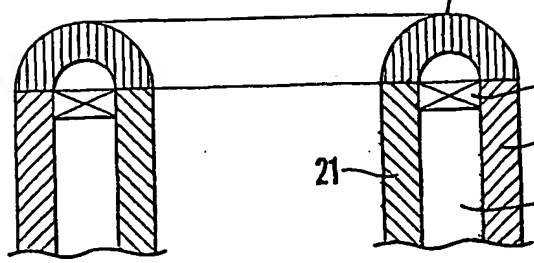


Fig.43

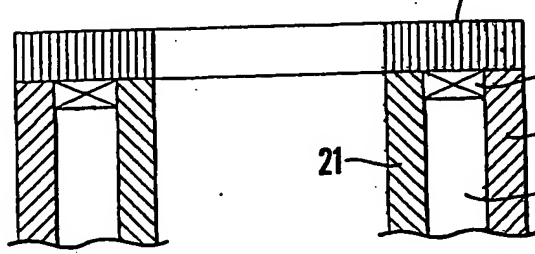


Fig.44

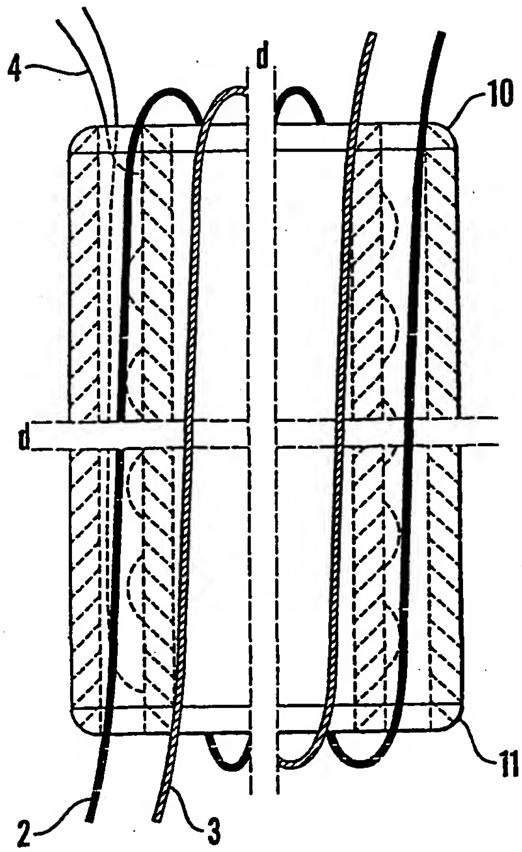


Fig.45a

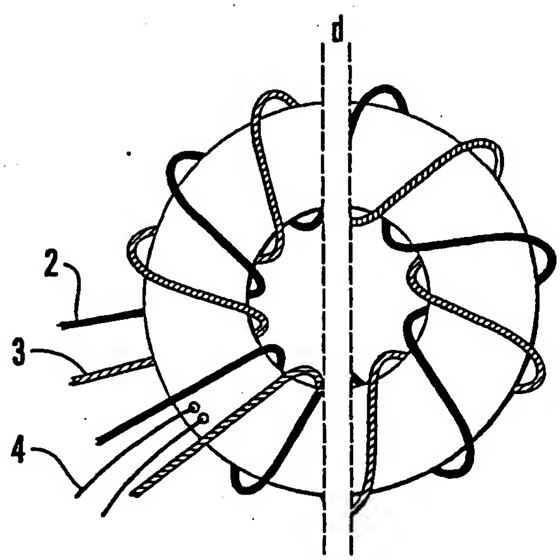


Fig.45b

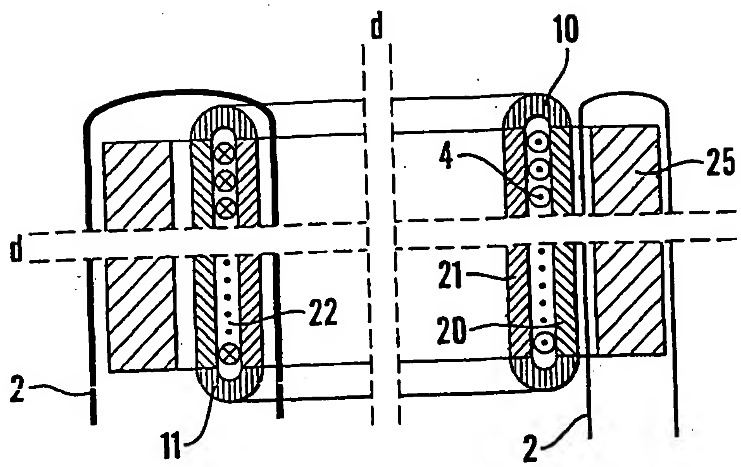


Fig.46a

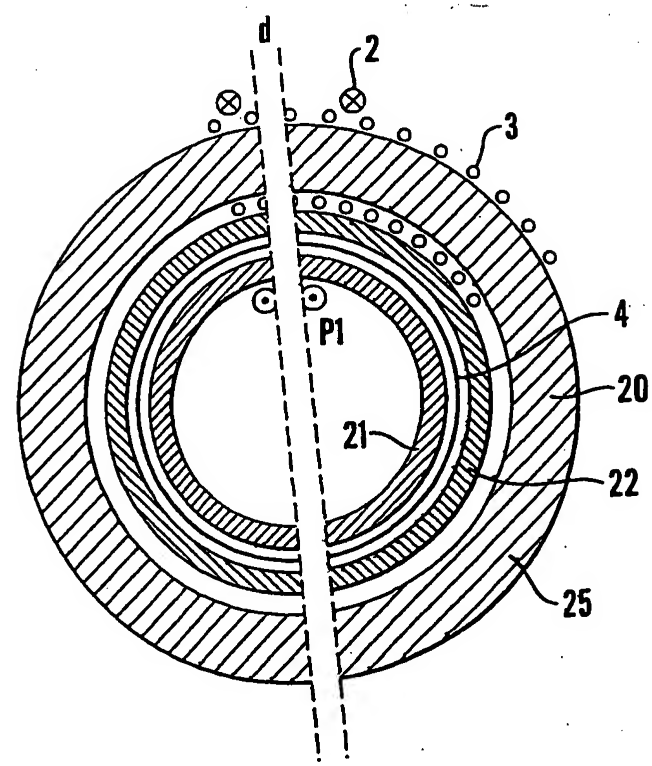


Fig.46b

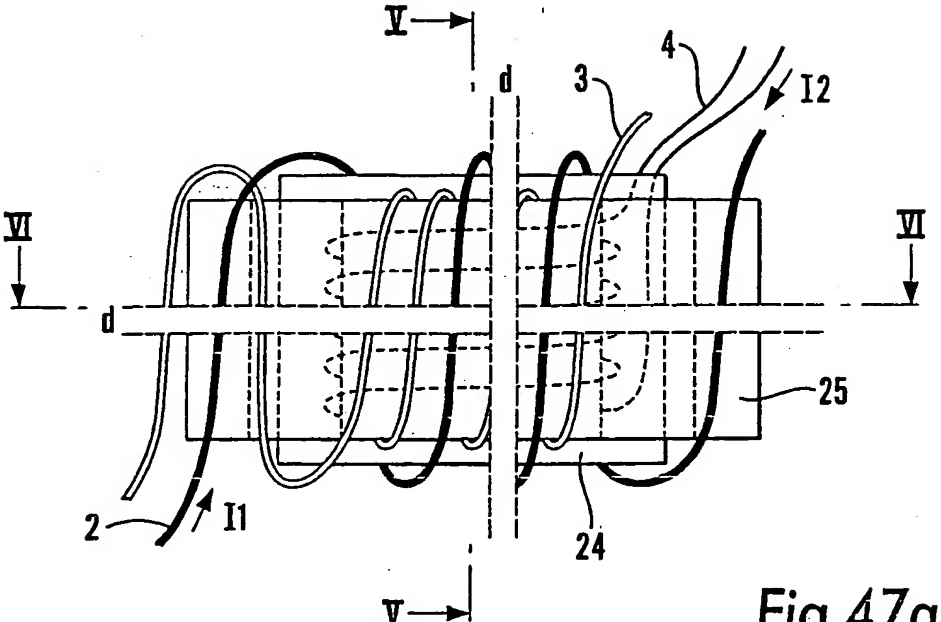


Fig.47a

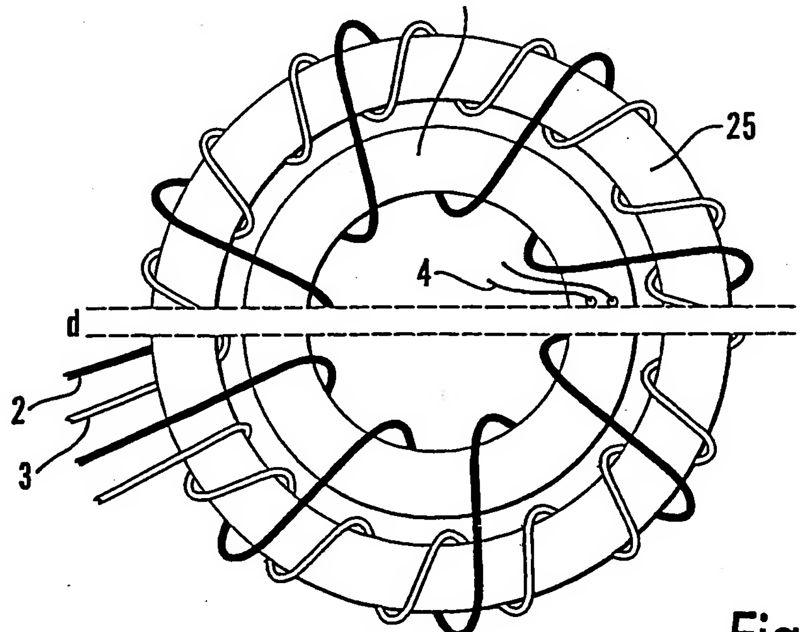


Fig.47b

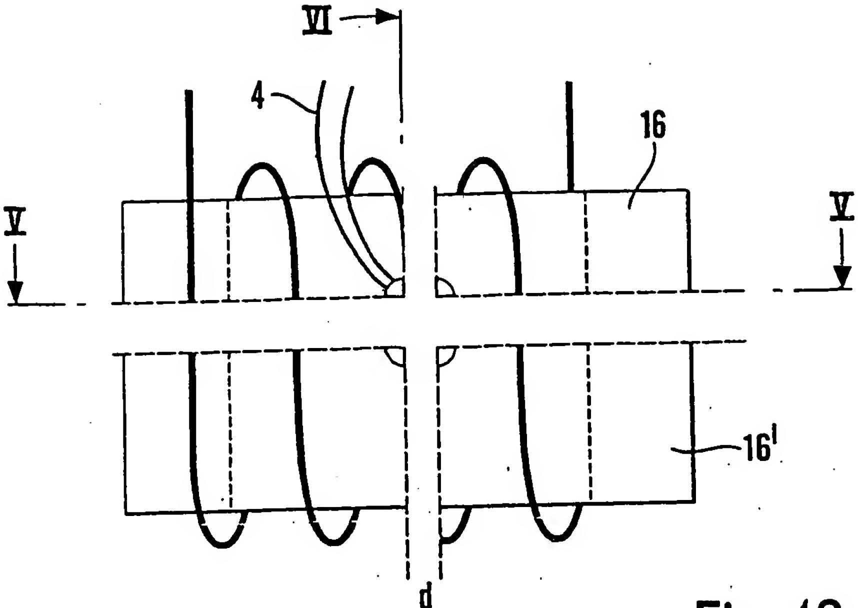


Fig.48

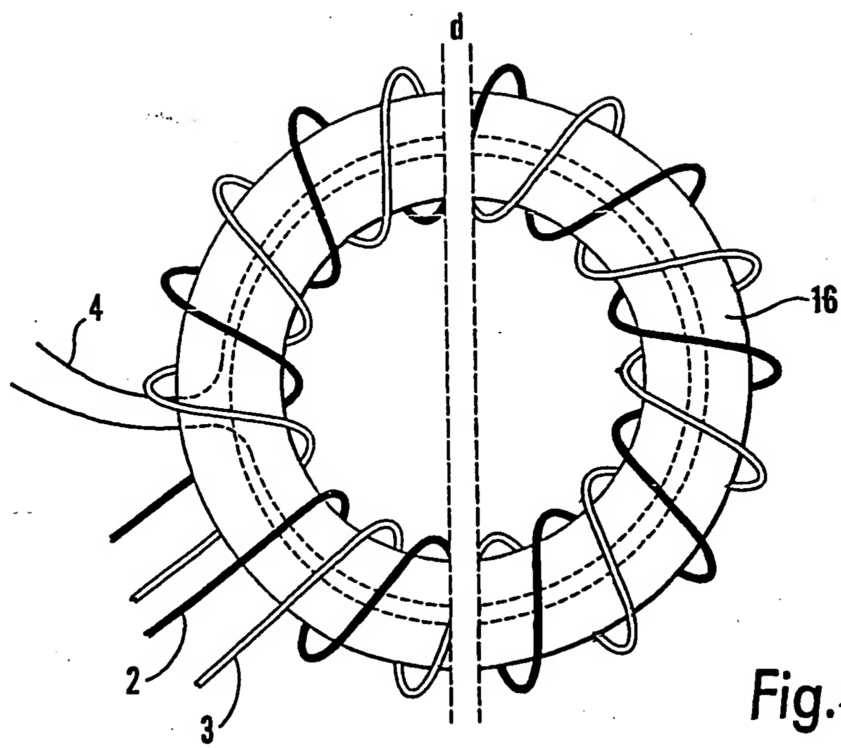


Fig.49

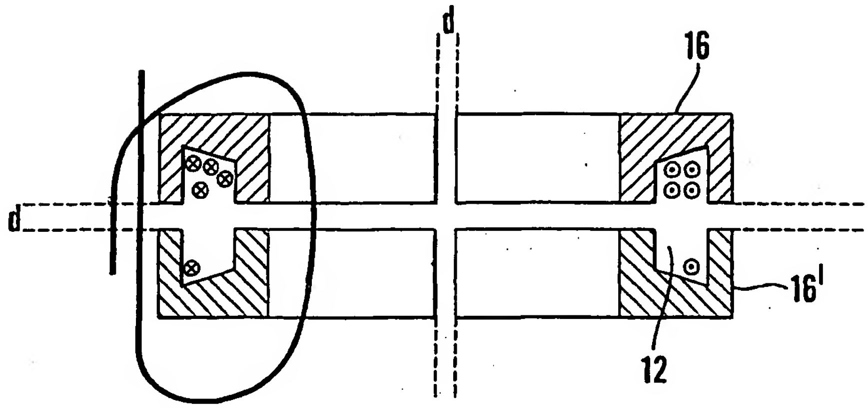
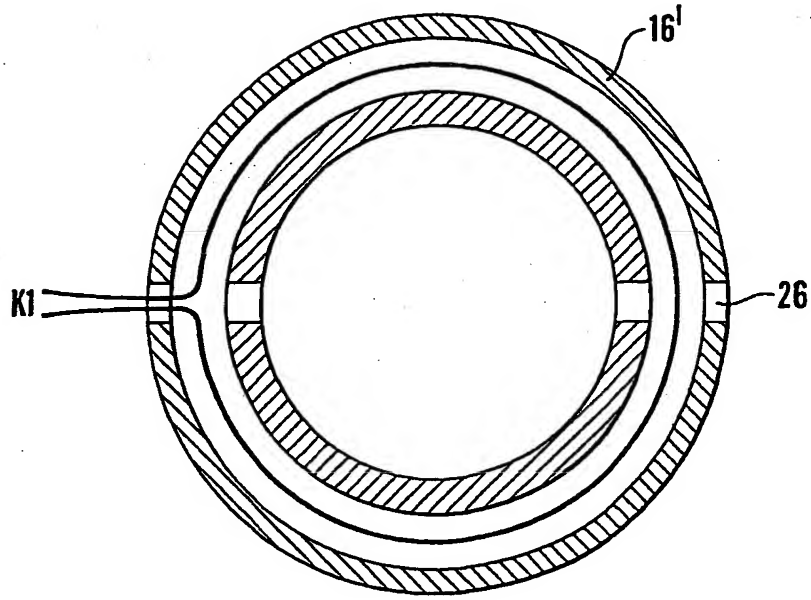


Fig.50



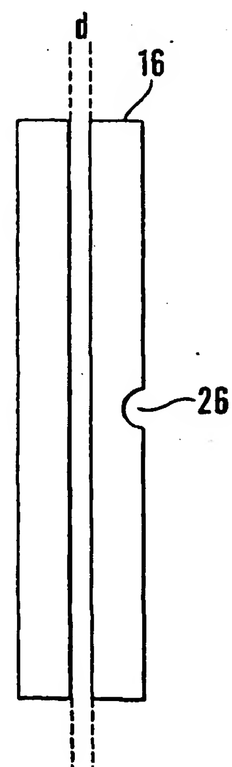


Fig.51a

Fig.51b

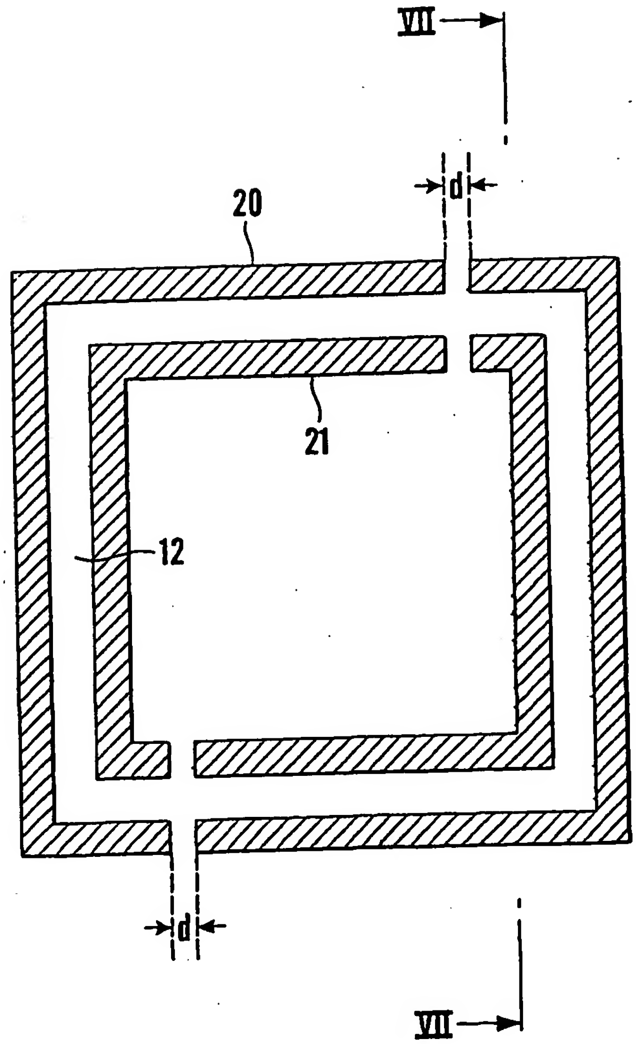


Fig.52a

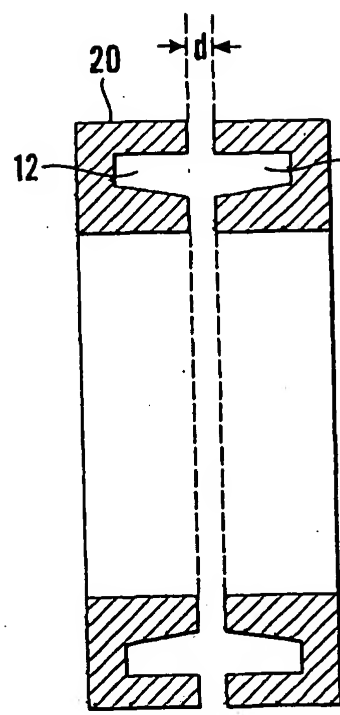


Fig.52b

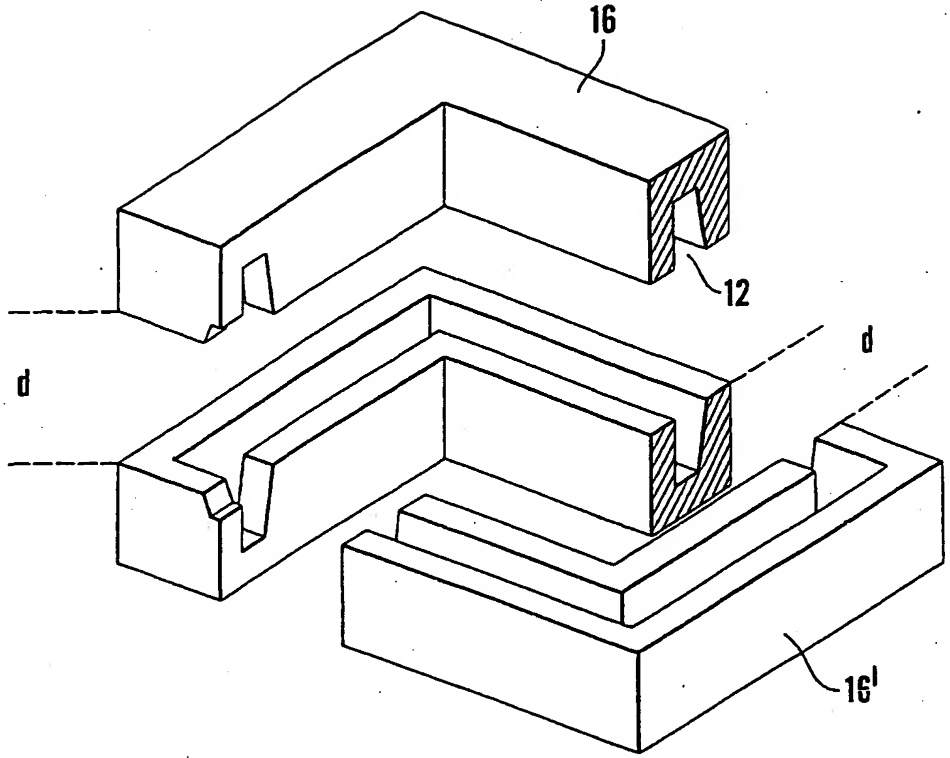


Fig.53a

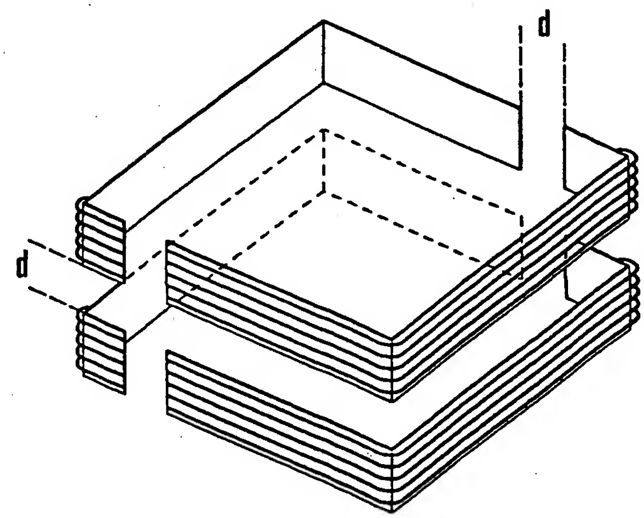


Fig.53b

Rear seat support members 98 are preferably similar to forward seat support members 96 in that rear seat support members 98 also include a U-shaped frame portion somewhat similar to that of U-shaped frame portion 150 of forward seat support members 96. The U-shaped frame portion of a rear seat support members 98 are illustrated in elevation in Figures Y through BB. Rear seat support members 98 preferably include a pair of spaced-apart vertically upstanding walls, one of which is visible in the view presented by Figures Y through BB and is designated 214 in the drawings.

Walls 214 are separated transversely sufficiently to receive longitudinally extending tubular member 110 therebetween as generally illustrated in Figures Y through BB. Walls 214 each preferably have parallel, transversely aligned forwardly opening longitudinally elongated slots formed therein, as shown in Figure BB. The slots in walls 214 of rear seat support members 98 are adapted to receive rear transverse rods 212 which are affixed to a lower portion of longitudinally extending tubular member 110 closer to the rear terminus thereof than to the forward terminus, all as illustrated in Figure BB. Hence, rear transverse rods 212 may be easily slid into the slots in walls 214 of rear seat support members 98.

Rear seat support members 98 and specifically walls 214 thereof are mounted on shafts 154 which, as described above, are preferably cylindrical in configuration to preferably slidably reside in holes drilled in the upper and lower portions of tubular members 62. Rear seat support members 98 are preferably retained in position respecting tubular members 62 using pins 158

influence of axial force applied to exterior surface 162 against force applied by spring 112.

As used herein, the "axial" force denotes force such as can be applied in a single direction by pushing with the palm of the hand. One of the major advantages of the power chair is that the seat in the embodiment illustrated in Figures Y through II may be removed from the frame and reengaged with the frame solely by application of such axial force such as may be applied using the palm of the hand. This is significant in that use of the thumb is not required. This is extremely helpful for elderly, infirm and handicapped persons such as those who through the effects of arthritis or other diseases or injury have lost use of or strength in the thumb and/or other fingers. Hence the axial force applied using the palm is applied in a single direction as by pushing with the palm.

Axially extending tubular members 110 preferably further include rear transverse rods 212 which are resident within rear arcuate cut-outs similar to forward arcuate cut-outs 208 illustrated in Figures HH and II but which have not been numbered in the drawings. Rear transverse rods 212 are preferably secured to longitudinally extending tubular members 110 similarly to forward transverse rods 206, preferably by welding. At the position on longitudinally extending tubular members 110 at which rear transverse rods are connected thereto, there is no slot analogous to axial slot 210 illustrated in Figures HH and II nor is there any spring or pushbutton structure analogous to that illustrated as pushbutton 114, spring 112 and exterior surface 162 in Figures HH and II.

contacted roll pin 164, pushbutton 114 has pushed hooking member 100 sufficiently that hooking member 100 has rotated into a position at which the mouth of the slide indicated by arrow J in Figure EE is slightly open upwardly, as illustrated by the phantom line depiction of hooking member 100 in Figure EE. This permits the user to lift seat 14 vertically upwardly thereby removing seat 14 from forward seat support member 96 without the use of tools.

Springs 168 are under compression. When manual force is applied to exterior button portion 166 in the axial direction indicated generally by double ended arrow M in Figures HH and II, pushbutton 114 moves to the left in Figures HH and II, against the resilient force applied to pushbutton 114 as a result of contact with spring 112.

Pushbutton 114 is relieved at the bottom, as illustrated in Figure II, to provide clearance above a transverse rod 206 which is fixedly retained within an arcuate cut-out 208 formed in the bottom of longitudinally extending tubular member 110 as illustrated in Figure II. Rod 206 is preferably secured to tubular member 110 by welding.

The relief provided in pushbutton 114 as illustrated in Figure II permits pushbutton 114 to travel axially within tubular member 110, under the influence of axial force applied to exterior surface 162 with pushbutton 114 moving to the left in Figure II, past transverse rod 206. A longitudinally elongated slot 210 is provided in the bottom of tubular member 110 as illustrated in Figure HH. Pushbutton 114 can traverse substantially the longitudinal length of slot 210 under the

respecting Figure HH and it is for this reason that pushbutton 114 in Figure II appears to be a two part member. In fact, pushbutton 114 is a single, unitary member having an opening thereon appearing as an open space in Figure II which registers with slot 210 illustrated in Figure HH.

A roll pin 164 extends through the walls of tubular member 110 and limits axial travel of pushbutton 114.

The open void appearing in pushbutton 114 in Figure II, which open void has been designated 168, registers with slot 210 and also with a space within pushbutton 114 occupied by spring 112. Spring 112 is maintained in compression between roll pin 164, which is stationary respecting pushbutton 114, and an unnumbered internal shoulder portion of pushbutton 114 against which spring 112 abuts at its right hand extremity viewed in Figure II.

With spring 112 being under compression, a user applying manually generated axially oriented force to exterior surface 166 urges pushbutton 114 to the left in Figures HH and II. The left hand surface of pushbutton 114, at the end opposite from surface 166, passes over forward transverse rod 206 since there is a slight clearance provided between the surface of pushbutton 114 facing rod 206 and rod 206 itself. This clearance permits pushbutton 114 moving to the left to contact hooking member 100 thereby rotating hooking member 100 in the direction indicated by arrow A, against the bias applied thereto by spring 102. When pushbutton 114 has traveled the full permissible length of its longitudinal travel within tubular member 110 and a shoulder portion at the right hand end of space 168 in Figure II has

longitudinally extending rigid tubular members designated 110 affixed to the bottom of cushion 20 of seat 14. Longitudinally extending tubular members 110 are visible in Figures N, O, Q, R, T and Y through DD and are shown partially broken in Figures HH and II. Subframe 108 may further include a pair of transverse rigid tubular members, longitudinally separated from one another, extending between and secured to inwardly facing surfaces of longitudinally extending members 110. These transversely extending members are numbered 111 and are visible in Figure O.

Seat 14, specifically cushion portion 20 of seat 14, may be secured to rigid subframe 108 via screws passing through tubular members 111 and into the bottom of cushion portion 20 of seat 14. Tubular members 111 are separated from the lower, downwardly facing surface of cushion 20 of seat 14 by thermoplastic washers which are illustrated in Figure 7. Neither the screws which pass through the thermoplastic washers to secure tubular members 111 to the bottom portion of cushion portion 20 of seat 14 nor the thermoplastic washers themselves have been numbered in Figure O, to aid drawing clarity.

Longitudinally extending tubular members 110 preferably house pushbuttons 114 having coil springs 112 therewithin as illustrated in Figures HH and II. Pushbutton 114 has a portion 162 which extends longitudinally out of tubular member 110 and a longitudinally facing end surface 166 adapted for receiving axial manually generated force to move pushbutton 114.

Pushbutton 114 is preferably of unitary construction. The section view illustrated in Figure II is a vertical section

12 independently one of another. This permits cushion portion 20 of seat 14 to be affixed to frame 12 in a level position, which is effectuated by seat support members 96, 98 being at a common height respecting longitudinally extending tubular upper member 62 in which forward and rear seat support members 96, 98 reside. Cushion 20 may be tilted back; this is effectuated by having upstanding forward seat support members 96 positioned higher respecting associated member 62 of frame 12 than rear upstanding seat support members 98 respecting associated member 62 of frame 12.

Further alternatively, cushion 20 may be positioned tilted forward by having rear upstanding seat support members 98 positioned higher respecting associated member 62 of frame 12 than forward upstanding seat support members 96. Because the vertical position of upstanding seat support members 96, 98 may be adjusted manually, without use of tools, this permits an attendant or therapist to change the seating position for the power chair user at the home or other premises where the power chair is used; it is not necessary to take the power chair to a dealer or other service facility or to a health care facility to adjust seat height/tilt position.

Seat 14 may be mounted on and may be considered to include a rigid subframe designated generally 108 which provides a part of means for connecting seat 14, specifically cushion 20 of seat 14, to frame 12 of power chair 10 so that seat 14 is releasably supported above frame 12 and may be removed from frame 12 by hand, without the use of tools.

Subframe 108 may include a pair of circular cross-section

attached to pin 158 by passage through an aperture at one end of pin 158 as indicated generally by double ended arrow B in Figure GG. Once pin 158 has been removed from a given horizontal semi-circular bottomed groove 156 and is outside tubular member 62, the associated forward or rear seat support member 96, 98 may be moved vertically, either up or down as desired; this vertical adjustment is indicated schematically by double ended arrow L in Figure FF.

When the seat support member 96 or 98 is in the desired position, pin 158 is replaced. This is done by pushing pin 158 through the aligned apertures in the parallel side walls of tubular member 62 and into position in the desired semi-circular bottomed groove 156 in shaft portion 154 of the associated forward or rear seat support member 96, 98, as depicted by double ended arrow B in Figure GG. This secures seat support member 96 or 98 against rotation since pin 158 is precluded from rotating about the axis of shaft 154 by interference with the walls of member 62. Seat support member 96 or 98 is precluded from moving vertically, being held in place respecting vertical movement by pin 158 residing within a preferably semi-circular bottomed groove 156 formed in shaft portion 154 of an associated seat support member 96 or 98.

Figures FF and GG depict the interaction of a forward upstanding seat support member 96 and pin 158 and the manner of effectuating vertical position adjustment of upstanding seat support member 96; the same structure is provided for rear seat support members 98. Hence, front and rear seat support members 96, 98 may preferably be positioned vertically respecting frame

respecting longitudinally extending tubular upper member 62 independently of one another thereby to permit adjustment of height and/or tilt of seat 14, specifically cushion portion 20 of seat 14, respecting frame 12.

Height adjustment of forward and/or rear upstanding seat support members may be preferably performed manually, without use of tools. This is preferably facilitated by mounting forward and rear upstanding seat support members 96, 98 in apertures formed in members 62 as depicted generally in Figures FF and GG. Upstanding seat support members 96, 98 preferably have shaft portions 154 which are preferably cylindrical in configuration to preferably slidably reside in the apertures defined by holes in the upper and lower portions of members 62. Preferably, horizontal semi-circular bottomed grooves 156 are formed in shafts 154, are vertically spaced from one another and an aligned at a common position on the periphery of shaft 154, as illustrated in Figure EE.

Side walls of members 62 are drilled to receive pins 158 which slidably reside within the holes drilled in the side walls of members 62. Each pin 158 is sized to fit in a selected one of horizontal semi-circular bottomed grooves 156 formed in shaft portion 154, as illustrated generally in Figures FF and GG. One pin 158 is provided for each of upstanding seat support members 96, 98 to retain the same in place respecting an associated member 62.

To adjust vertical position of one of seat support members 96, 98, associated pin 158 is removed. This is normally accomplished by pulling on a pull ring 160 which is preferably

as illustrated generally in Figure EE, where arrow A denotes rotational movement of hooking member 100. In Figure EE a hooking member 100 is shown in phantom lines having rotated in the direction of arrow A from its normal operational position illustrated in solid lines in Figure EE.

Hooking members 100 are adapted to rotate rearwardly, as indicated by arrow A in Figure EE, to an orientation such that mouth portions of the hooking members preferably move at least to a horizontal orientation so that seat 14 may be removed from seat support members 46 and specifically from forward upstanding seat support members 96.

Springs 102 are provided about shafts 104 to bias hooking members 100 forwardly respecting Figure EE, in a direction opposite to that indicated by arrow A, to an orientation at which the mouth portion of a slot in hooking member 100 is preferably facing below horizontal as illustrated in solid lines in Figure EE. The mouth portion of hooking member 100 is designated generally 106 by arrow J in Figure EE and is defined by an opening between a tip 152 of hooking member 100 and a remaining surface of the slot formed in hooking member 100.

As depicted schematically by double ended arrow L in Figure FF, upstanding seat support portions 46, specifically forward and rear upstanding seat support members 96, 98, are preferably movable upwardly respecting the remainder of frame 12 and specifically respecting longitudinally extending tubular member 62 to which respective forward and rear upstanding seat support members 96, 98 are connected. Forward and rear seat support members 96, 98 are preferably vertically adjustably positionable

rod welded to it is retained in place within box-like connecting member 496 by a nut visible but not numbered to aid drawing clarity.

As illustrated in Figures N, O, Q, R, T and Y through II, power chair 10 may include rigid means for releasably supporting seat 14 on frame 12 where frame 12 includes rigid upstanding extension portions for supporting seat 14. These upstanding portions are designated generally 46 in the drawings and specifically include preferably rigid rear upstanding seat support members designated 98 and preferably rigid forward upstanding seat support members 96, which are shown in Figures N and O and especially in Figure Q.

Rear seat support members 98 extend upwardly, preferably vertically, from respective side members 460, 462 or frame 12 and are transversely spaced one from another. Similarly, forward seat support members 96 extend upwardly, preferably vertically, from respective side members 460, 462 of frame 12 and are transversely spaced one from another. Rear seat support members 98 preferably include slots, which are preferably horizontally disposed, and which preferably face forward seat support members 96. These slots are visible in Figures Q, R, Y, Z and BB but have not been numbered to enhance drawing clarity.

As illustrated in Figures Y, CC and DD, forward seat support members 96 preferably include hooking members 100 which are preferably pivotally mounted in rigid U-shaped frame portions 150 of forward seat support members 96. Hooking members 100 are preferably mounted on shafts 104 to be movable by rotation respecting frame portion 150 of forward seat support members 96

against the pair of transverse members 404 constituting lower forward transversely extending foldable members 68.

When footrest 172 is to be removed prior to folding the power chair frame 12, footrest 172 together with box-like connecting member 496 is merely lifted until the cylindrical members are aligned with the curved cutouts in vertically oriented central connection beam 412 whereupon footrest 172 and box-like connecting member 496 may be moved forward relative to frame 12, out of engagement with frame 12.

A transversely extending pivot pin provides pivotal connection between the pan portion of footrest 172 and box-like connecting member 496 thereby permitting the pan portion of footrest 172 to be tilted upwardly by pivotal motion about pivot pin 258 respecting box-like connecting member. The pivotal connection between footrest 172 and box-like connecting member 496 provides a snap action whereby the pan portion of footrest may be snapped from a horizontal orientation at which the power chair occupant's feet may rest on the footrest pan, to a vertical orientation, for storage and otherwise minimizing the effective length of the power chair.

The snap action is provided by roll pivot pin 258 having a rod axially aligned with the roll pin and welded to the roll pin forming one portion of the pivotal connection and a piece of arcuate spring steel 900 forming the other portion of the pivotal connection. Interference between the rod welded to the roll pivot pin 258 and the piece of spring steel 900 provides spring-like snap action as the footrest pan is pivoted between vertical and horizontal positions. Most desirably the roll pin with the

rods 422 and contributes to stability of frame 12 when unfolded and in operating configuration. This construction facilitates rapid and facile disassembly and reassembly of foldable power chair 10 when it is desired to fold the power chair for transport and then to unfold it and use it in a new locale. With this construction, no tools are required for disassembly and reassembly of the midwheel drive foldable power chair.

As illustrated in Figure 7, the power chair includes a footrest 172 which is detachable to permit folding of the foldable power chair 10. Footrest 172 is connected to upstanding vertically oriented central connection beam 412 by a box-like connecting member 496 which is preferably bolted to beam 412. Rigidly affixed to one end of box-like connecting member 496 are a pair of cylindrical members 498 which are sized for fitting into a pair of curved cutouts 498 formed in vertically oriented central connection beam 412.

The pair of cylindrical members extend from the rear surface of a plate defining terminus of box-like connecting member 496 where the plate is designated 502 in Figure 7. Relief cutouts formed in the pair of cylindrical members are sized to receive a forward wall of vertically oriented central connection beam 412 which is preferably of box-like construction. When the cylindrical members are inserted into the curved cutouts in vertically oriented central connection beam 412, the relief cutouts receiving the forward wall of vertically oriented central connection beam 412 permit box-like connecting member with the attached cylindrical members and plate 502 to slide down vertically oriented central connection beam 412 and come to rest

As illustrated in Figure 6, a removable tray 70 is provided for carrying electrochemical means, namely one or more batteries, for powering the motors rotating drive wheels 16. Longitudinal rods 422 running along the bottom of frame 12 support the tray 70 as seen in Figures 5 and 6. Rods 422 extend rearwardly from respective ones of members 404 constituting lower forward transversely extending foldable member 68 to rear transverse member 464, as illustrated in Figures 1 and 5. Rods 422 are connected to members 404 and 464 by pivotal connections 546 allowing relative rotation between rods 422 and members 404 and 464, facilitating folding of frame 12. The tray 70 has slots or recesses 548 formed on the bottom for receiving longitudinal rods 422. Weight of a battery bearing downwardly on tray 70 effectively secures tray 70 to rods 422 and hence to frame 12. Tray 70 is preferably an injection molded or thermoformed plastic body of unitary construction.

Tray 70 preferably has a series of progressively larger recesses or ridges 550 formed in the upwardly facing surface 552, to accommodate different sizes and models of batteries from various manufacturers. In the lower surface, channels or recesses 548 receive longitudinal rods 422 running from front to back of frame 12 when tray 70 is laid on longitudinal rods 422. Longitudinal rods 422 are pivotally connected to the pair of transverse members 404 and pivot when foldable power chair 10 is folded. When frame 12 is unfolded, tray 70 is placed down on longitudinal rods 422 and the longitudinal rods 422 are received in recesses 548 formed on the bottom of tray 70. Weight of a battery riding on tray 70 is in turn transferred to longitudinal

5.

Referring to Figure 4, power chair 10 includes two motors, only one of which is illustrated in Figure 4 for independently driving respective drive wheels 16. These motors are each designated generally 76 and are each preferably within a rigid casing which houses, in addition to motor 76, a transmission 78 for transferring driving rotation from an output shaft of a motor 76 to an associated drive wheel 16. There is no common single axle for drive wheels 16 in the preferred embodiment of the invention.

Motor 76 and transmission 78 are available from Rockwell Automation in Eden Prairie, Minnesota. Transmission 78 is preferably a right angle worm drive serving to change the axis about which the driving rotation is provided by motor 76. Specifically, motor 76 is positioned so that the motor output shaft extends substantially longitudinally. Associated transmission 78 through the right angle worm drive provides the driving rotation output via an axle, not numbered in the drawings, connecting to an associated drive wheel 16.

A shift lever 79 extending out of transmission 78 may be rotated to disengage transmission 78 thereby providing free wheel operation of drive wheels 16. By twisting shift lever 79, the power chair operator can switch from driven to freewheeling operation of drive wheels 16.

Motor 76 and transmission 78 are rigidly connected by motor/transmission housing 80. Motor and transmission housing 80 is preferably glass filled nylon, which is extremely strong and provides quite operation.

Referring to Figures 4 and 14, each combination side member 460, 462 includes not only a longitudinally extending member 62 and a vertical member 66 but also a longitudinally extending motor support member 482 which is secured to vertical member 66 proximate the vertical midpoint thereof and extends rearwardly from vertical member 66 preferably parallel with longitudinally extending member 62. Motor support member 482 is connected to longitudinal extending member 62 by a preferably triangular web 484 and by a preferably vertical bracing member 486 as illustrated in Figures 4 and 14. Connections among motor support member 482, triangular web 484, bracing member 486, vertical member 60 and longitudinal member 62 are preferably by welding since all of the structures are preferably steel. This construction provides high strength/high rigidity combination side members 460, 462.

As illustrated in Figure 3, fenders 126 preferably rest directly on frame 12, are preferably a single molded piece of high impact plastic and are exceedingly light. Fenders 126 stay in place when frame 12 is folded and are preferably secured in place by push pins or bolts, which have not been illustrated in the drawings to enhance drawing clarity. Fenders 126 are preferably permanently connected to frame 12.

Referring to Figures 4 and 14, longitudinal member 62 includes a longitudinally extending major portion 488 and a downwardly sloped extension portion 490 having a receptacle member 492 at the end thereof which is adapted to receive a bearing assembly 144 which in turn receives a U-shaped spindle 142 in which an idler wheel 18 is mounted, as shown in Figure

idler wheel 18; cap portion 474 presents a generally cylindrical outward appearance while the inside portion of cap portion 474 is cut away to facilitate cap portion 474 fitting over spindle 142.

As shown in Figure 15, fender 126 further includes a transition portion 476 which connects cap portion 474 and planar portions 470 and 472 and still further includes a planar upwardly facing portion 478. Fender 126 is preferably secured to an associated side member 460 or 462 by securement of planar portions 470 and 478 to corresponding parts of side member 460 or 462.

As shown in Figure 15, fender 126 further yet preferably includes a forwardly facing integrally formed bumper member 480 which overlies and protects the spring-strut combination designated generally 44 governing upward movement of forward anti-tip wheels 42 relative to frame 12. Bumper member 480 is sufficiently elongated in the transverse or widthwise direction respecting fender 126 to cover the associated spring-strut combination 44.

Still referring to Figure 15, annular upwardly facing portion 468 is preferably transversely elongated sufficiently to cover the width of an associated drive wheel 16 and the portion of frame side member 460 or 462 adjacent to and immediately inboard of the associated drive wheel 16. Similarly, the planar portions 470 and 478 are sufficiently elongated in the transverse or widthwise direction respecting fender 126 to cover the associated portion of side member 460 or 462 in which fender 126 is mounted.

power chair 10 for transport or storage as shown in Figure 3.

Strap hook 418 can be used as an attachment for a leash for pulling foldable power chair 10 after it has been folded. Strap 416 is disconnected from strap hook 418 attached to transverse members 402 on the back of foldable power chair 10. Strap 416 is left connected to strap hook 418 affixed to vertically oriented central connection beam 412 on the front of the foldable power chair. As strap 416 is pulled, foldable power chair 10 follows.

As illustrated in Figure 3, a pair of fenders 126 are provided and preferably wrap substantially around upper semi-circular portions of respective drive wheels 16. Fenders 126 preferably extend outwardly preferably over at least major portions of the width of associated drive wheels 16, to fit closely about the drive wheel portions which are enveloped by respective fenders 126. Fenders 126 hide much of frame 12 from view and provide an aesthetically pleasing appearance.

As best illustrated in Figure 15 and as also apparent from Figure 3, each fender 126 includes a semi-circular inner edge 466 which fits closely about a drive wheel 16 when fender 126 is in place on frame 12. Fender 126 includes an arcuate transversely elongated upwardly facing portion 468, a sloped rearwardly facing planar portion 470, which is also transversely elongated and a planar outwardly facing side portion 472 which is essentially vertical when fender 126 is secured in position on frame 12 and essentially joins rearwardly facing planar portion 470 as these two surfaces approach the rearward extremity of fender 126. A cap portion 474 of fender 126 covers spindle 142 which carries

connections 414A and an intermediate one of which engages a pin 544. With the slots engaging these pin extensions 414, locking bar 400 is secured in place and foldable power chair 10 is retained in the open position, for operation.

Locking bar 400 may be swung away from the position illustrated in Figure 1 to the position illustrated in Figure 2, to facilitate folding of frame 12. Swinging locking bar 400 away from the position of securement causes locking bar 400 to disengage from the pivot pin extension at 414 and from pivot pin 544; hence locking bar 400 is disengaged from the vertically oriented central connection beam 412 and left upper transverse fixed beam member 406. Locking bar 400 is then pivoted out of the way on the extension of pivot pin connection 414 of the right transverse member 404 as illustrated in Figure 2.

As illustrated in Figure 1, a strap hook 418 is mounted on the upper extremity of vertically oriented central connection beam 412 at the front of the foldable power chair. Another strap hook 418 is mounted on rear transverse member 464, at the juncture of transverse members 402, at the rear of foldable power chair 10, as illustrated in Figure 21. A strap 416 has clamps on each end for engaging strap hooks 418 and may be secured to frame 12 of foldable power chair 10.

When strap 416 is secured to frame 12, foldable power chair 10 can easily be folded by pulling upward on strap 416. As strap 416 is lifted, vertically oriented central connection beam 412 moves upward and the pairs of transverse members 402 and 404 rotate upwardly. As frame 12 folds drive wheels 16 and idler wheels 18 move closer together, reducing width of the foldable

members 408 extend towards one another from inwardly facing surfaces, designated 410, of vertical members 66. The pair of upper transverse members 402 which are parts of member 64 and the pair of lower transverse members which are parts of member 68 are pivotally connected at their extremities remote from connection with respective transversely extending beam members 406, 408, to a vertically movable, vertically extending central connection beam 412. Suitable pivotal connections are provided by pin members 414 proximate transverse extremities of transverse members 402 and 404.

As illustrated in Figure 2 the power chair 10 may be folded into a configuration of reduced width, for transport or storage. Figure 2 provides a view of frame 12 together with other parts of chair 10 in the fully folded configuration looking at frame 12 from the front. Figure 21 provides a view of frame 12 in the fully folded configuration looking at frame 12 from the rear.

The rear portion of frame 12 of power chair 10 differs from the front portion of the frame 12 in that only a single transverse folding member 464 is provided, as illustrated in Figure 21. The rear view of frame 12 of foldable power chair 10 is analogous to the front view except there is no vertically oriented central connection beam 412 and locking bar 400.

As illustrated in Figures 1 and 2, in order to fold foldable power chair 10, locking bar 400 must be disengaged from frame 12. Locking bar 400 is pivotally connected to the left hand lower transverse fixed beam member 408 by a pivot pin connection 414. Locking bar 400 has downwardly facing notches, an extremity one of which engages a longitudinal extension of pivot pin

transverse shaft 234 extending between two legs of U-shaped spindle 228. A fitting resident on shaft 234 between the legs of spindle 228 receives a lower end of an upstanding strut 238. The upper end of strut 238 resides in a bushing 522 shown in Figure 1 and illustrated in detail in Figures 18 through 20 retained within a forward extending pedestal 202 which is fixedly connected and extends forward from the front facing surface of vertical member 66 of frame 12.

A coil spring 236 preferably surrounds upstanding strut 238 and is compressed between the fitting residing on transverse shaft 234 and forward extending pedestal 202 upon anti-tip wheels 42 encountering an obstacle or upon power chair 10 tipping forward and anti-tip wheels 42 contacting the ground.

Each of upper and lower forward transversely extending foldable members 64, 68 include a pair of transversely extending members where the two transversely extending members of upper member 64 are denoted 402 in Figure 1 and the two transversely extending members of lower member 68 are denoted 404 in Figure 1.

Respecting upper forward transversely extending member 64, each of transversely extending members 402 are movable pivotally about connections with a pair of transversely extending beam members 406, which extend towards one another from respective inwardly facing surfaces of vertical members 66 proximate the upper ends of vertical members 66. Transversely extending beam members 406 are fixedly connected to facing surfaces of vertically extending members 66, preferably by welding.

A similar pair of lower forward transversely extending beam

transversely centered respecting frame 12.

Foldable power chair 10 preferably includes a seat, which has not been illustrated in Figure 1 so as to more clearly show the details of frame 12.

Foldable power chair 10 further includes a pair of anti-tip wheels 42 located at the forward end of power chair 10 and connected to frame 12 by a pair of spring-strut combinations designated generally 44 in Figure 1.

Two pairs of upstanding seat support members are provided with each seat support member by designated generally 46. Members 46 may be provided to support a seat for carrying an occupant using foldable power chair 10. The two forward seat support members are designated generally 96 in Figures 1, 2 and 3 while the two rearward seat support members are designated generally 98 in Figure 5.

Rear idler wheels 18 are preferably connected to frame 12 by a pair of U-shaped spindles 142 with spindles 142 housing bearing assemblies 144 in upper portions thereof. Spindles 142 and bearing assemblies 144 connecting rear idler wheels 18 to frame 12 are not visible in Figure 1 but are visible in Figure 5.

Each spring-strut combination 44 preferably further includes a generally U-shaped or wishbone configuration spindle 228 which extends forwardly from and is pivotally connected to vertical member 66 forming a part of frame 12. The pivotal connection of U-shaped spindle 228 to vertical member 66 is not visible in Figure 1.

Spring-strut combination 44 further preferably includes a

members 66 are designated 460 and 462 respectively in Figures 1, 4 and 14. Side member combinations 460, 462 are connected together by three transversely extending foldable members, individually generally designated 64, 68 and 69 and illustrated in Figures 1 and 21, which facilitate the folding of frame 12 to bring the side frame members defined by combinations 460, 462 of longitudinally extending members 62 and vertical members 66, closer together. Frame 12 is illustrated in Figure 1 in a configuration with side member combinations 460, 462 separated one from another, as they would be configured while chair 10 is operating.

Side members 460, 462 defined by combinations of longitudinally extending members 62 and vertical members 66 are preferably respectively movably connected in part together by forward transversely extending foldable members 64, 68 with the upper forward transversely extending foldable member being designated 64 and the lower forward transversely extending foldable member being designated 68 in Figure 1. A third transversely extending foldable member 69 illustrated in Figure 21 is preferably located at the rear of frame 12 and further serves to connect the two side member combinations 460, 462 together.

Foldable power chair 10 includes a pair of drive wheels, each designated 16 in the drawings, and preferably a pair of idler wheels 18 located behind respective drive wheels 16. It is feasible, but less desirable, to provide only a single idler wheel located at the rear of the power chair. When a single rear idler wheel is provided, the single rear idler wheel is

curb illustrated in Figure RR.

Figure TT is a broken side view of the suspension apparatus for a curb-climbing power chair drive wheels and forward anti-tip wheels taken at arrows 21-21 in Figure P, with the drive wheel illustrated in phantom and with the drive wheels and the forward anti-tip wheels on a common downgrade.

Figure UU is a broken side view of the suspension apparatus for the curb-climbing power chair drive wheels and forward anti-tip wheels taken at arrows 21-21 in Figure P with the drive wheel illustrated in phantom, similarly to Figures U and NN through TT showing the drive wheels descending from a curb and with the forward anti-tip wheels contacting grade.

Figure VV is a broken plan view, taken looking upwardly at arrows 48-48 in Figure NN, of another embodiment of the suspension apparatus showing the fixedly connected curb-climbing power chair motor housing and spindle for the forward anti-tip wheels illustrated in Figures NN through UU.

Description of the Invention

Referring to the drawings in general and to Figure 1 in particular, a power chair designated generally 10 includes a frame which has been designated generally 12. Frame 12 preferably includes a pair of longitudinally extending members 62, visible in Figures 4 and 14 on either side of frame 12, a pair of preferably vertically extending members 66 which extend vertically downwardly from forward ends of longitudinally extending members 62, where the side member combinations defined by longitudinally extending members 62 and vertically extending

Figure P and with the drive wheel illustrated in phantom similarly to Figure U.

Figure NN is a broken schematic side view of the suspension apparatus for the curb-climbing power chair drive wheels and forward anti-tip wheels, taken at arrows 21-21 in Figure P, with the drive wheel illustrated in phantom similarly to Figure U.

Figure OO is a broken side view of the suspension apparatus for the curb-climbing power chair drive wheels and forward anti-tip wheels similarly to in Figure NN with the drive wheel illustrated traversing a small bump.

Figure PP is a broken side view of the suspension apparatus for the curb-climbing power chair drive wheels and forward anti-tip wheels illustrated in Figures NN and OO, taken at arrows 21-21 in Figure P and with the drive wheel illustrated in phantom similarly to Figure U, with a drive wheel further illustrated as being on a curb member elevated respecting grade and the forward anti-tip wheels contacting grade.

Figure QQ is a view identical to Figure 40 and is presented for contrast with Figure PP.

Figure RR is a broken side view of the suspension apparatus for a curb-climbing power chair drive wheels and forward anti-tip wheels taken at arrows 21-21 in Figure P, with the drive wheel illustrated in phantom and with the forward anti-tip wheels encountering a vertical edge of a high curb.

Figure SS is a broken side view of the suspension apparatus for the curb-climbing power chair drive wheels and forward anti-tip wheels taken at arrows 21-21 in Figure P, with the drive wheel and with the forward anti-tip wheels on the top of the high

connecting the seat to the frame.

Figure DD is a side view taken at the same position as Figure CC illustrating the seat subframe ready to engage a latch portion of means for releasably connecting the seat to the frame.

Figure EE is a side view of the latch illustrated in Figures CC and DD, depicting movement of latch parts.

Figure FF is a view of the portion of the frame and the latch illustrated in Figures CC and DD, taken at the same position, illustrating vertical adjustment of a seat support member.

Figure GG is a front elevation of the structure illustrated in Figure FF taken at arrows 33-33 in Figure FF.

Figure HH is a partially broken view of a portion of a seat subframe taken at arrows 34-34 in Figure DD.

Figure II is a partially broken side view of structure illustrated in Figure HH.

Figure JJ is a side view of an arm of a power chair seat as illustrated generally in Figures Y through BB showing the manner in which the arm may be swung upwardly.

Figure KK is an enlarged view of structure illustrated in Figure JJ taken at circle 37 in Figure JJ.

Figure LL is an enlarged view of structure illustrated in Figure T taken at the position indicated by the circle in Figure T.

Figure MM is a broken side view of a further alternate embodiment of suspension apparatus for the power chair drive wheels and forward anti-tip wheels taken at arrows 21-21 in

illustrating operation of the drive wheel suspension upon the drive wheel encountering an obstacle.

Figure W is identical to Figure U and is presented for purposes of ready reference when considering Figure X.

Figure X is a side view of one embodiment of the drive wheel and forward anti-tip wheel independent suspension apparatus illustrated in Figures U through W, taken at arrows 24-24 in Figure P and illustrating aspects of operation of anti-tip wheel suspension apparatus.

Figure Y is a broken side view of the seat and an upper portion of the frame of the power chair illustrated in Figures N through R showing means operable responsively to manually generated force for releasably connecting the seat to the frame.

Figure Z is a broken side view of the seat and an upper portion of the frame of the power chair as illustrated in Figure Y showing the seat support structure partially engaged with the frame.

Figure AA is a broken side view of the seat and an upper portion of the frame similar to Figures X and Z showing the power chair seat mounted on the frame in a position tilted back relative to the position illustrated in Figure Y.

Figure BB is a broken side view of the seat and an upper portion of the frame, similar to Figures Y through AA, depicting operation of means for releasably connecting the seat to the frame.

Figure CC is a side view taken at the position of circle 29 in Figure Y illustrating a latch portion of means for releasably

chair.

Figure O is a rear view of the power chair illustrated in Figure N with the power chair body similarly removed to reveal internal structure and mechanical details.

Figure P is a top view of the power chair illustrated in Figures N and O but with the power chair seat and body removed to reveal internal structure and mechanical details.

Figure Q is an exploded side view of the power chair illustrated in Figures N through P taken in the same direction as Figure 14 and illustrating the manner in which the power chair batteries, body and seat are assembled.

Figure R is a partially exploded side view of the power chair illustrated in Figures N through Q taken looking in the same direction as Figure 17 with the batteries and power chair body in position and supported by the power chair frame and with the power chair seat illustrated removed from the frame and above the frame/body assembly.

Figure S is an isometric view of the frame of the power chair.

Figure T is a view of the power chair seat back looking in the same direction as Figure O, illustrating power chair seat arm width adjustment aspects of the invention.

Figure U is a broken side view of the power chair independent drive wheel suspension, taken at arrows 21-21 in Figure P, with the drive wheel illustrated in phantom.

Figure V is a broken side view of the embodiment of the power chair suspension illustrated in Figure U, taken at arrows 21-21 in Figure P, with the drive wheel illustrated in phantom,

Figure 12.

Figure A is a right side view of a power chair of the type to which this application generally pertains.

Figure B is a front elevation of the power chair shown in Figure A.

Figure C is a rear elevation of the power chair shown in Figures A and B.

Figure D is a left side view of the power chair shown in Figures A through C.

Figure E is a top view of the power chair shown in Figures A through H.

Figure F is a bottom view of the power chair shown in Figures A through E.

Figure G is a perspective view looking at the right front of the power chair shown in Figures A through F.

Figure H is a right side view of a power chair similar to that shown in Figures A through G.

Figure I is a front view of a power chair shown in Figure H.

Figure J is a rear view of a power chair shown in Figures G and H.

Figure K is a left side view of a power chair shown in Figures H through J.

Figure L is a top view of a power chair shown in Figures H through K.

Figure M is a perspective view looking at the right front of the power chair shown in Figures H through L.

Figure N is a side view of another embodiment of a power

Figure 15 is a side view of a fender for one side of the frame usable with the midwheel drive foldable power chair illustrated in Figures 1 through 6.

Figure 16 is a side view of an adjustable back assembly for a seat usable with the midwheel drive foldable power chair illustrated in Figures 1 through 6, showing the back of the seat in an upright position.

Figure 17 is a side view of the adjustable back assembly for a seat usable with the midwheel drive foldable power chair illustrated in Figures 1 through 6, showing the back of the seat in a folded position.

Figure 18 is a front elevation of a bushing which is a part of the anti-tip wheel spring pivot support apparatus visible in Figures 1 and 2.

Figure 19 is a bottom view of the bushing illustrated in Figure 18.

Figure 20 is a side view of the bushing illustrated in Figures 18 and 19.

Figure 21 is a rear elevation view of the frame portion of a midwheel drive foldable power chair illustrated in Figures 1 through 6, showing the frame in a folded configuration.

Figure 22 is a side view of a midwheel drive foldable power chair of the type having a frame as illustrated in Figures 1 through 6.

Figure 23 is a top view of a midwheel drive foldable power chair having a frame as illustrated in Figures 1 through 6, including a parallelogram linkage assembly for the joystick power chair movement control device, as depicted schematically in

chair embodying aspects of the invention.

Figure 8 is a front view of a chair seat and chair back connecting structure usable with a power chair having a frame as illustrated in Figures 1 through 6.

Figure 9 is an isometric view taken from this front of a patient transfer seat usable with a power chair having a frame as illustrated in Figures 1 through 6, showing the transfer seat in an unfolded position for transfer of a patient.

Figure 10 is a two part drawing of a disassembled arm lock apparatus usable with a power chair having a frame as illustrated in Figures 1 through 6, with one part of the drawing being a plan view and the second part being an isometric.

Figure 11 is an exploded top view of the arm lock apparatus shown in Figure 10, with the lock portion of the apparatus disassembled.

Figure 12 is a top view of a locking parallelogram linkage for supporting and positioning a joystick controller, usable with a power chair having a frame as illustrated in Figures 1 through 6.

Figure 13 is a front view of a frame for an adjustable width power chair manifesting aspects of the invention.

Figure 14 is a side view looking outwardly from the interior of the frame for the power chair at the position indicated generally by arrows 14-14 in Figure 3 showing the pivotal connections of U-shaped spindles to vertical members for a midwheel drive foldable power chair having a frame as illustrated in Figures 1 through 6, in accordance with the preferred embodiment of the invention.

midwheel drive power chair showing the frame in an unfolded configuration with a locking bar in the locked position in accordance with the preferred embodiment of the invention.

Figure 2 is a front view of the frame portion of a power chair showing the frame in a fully folded configuration with the locking bar in the unlocked position in accordance with the preferred embodiment of the invention.

Figure 3 is a front view of the frame of a power chair illustrated in Figures 1 through 2, with the frame in the fully folded configuration and with two fenders in place on the folded frame in accordance with the preferred embodiment of the invention.

Figure 4 is a side view looking outwardly from the interior of the frame at the position indicated generally by arrows 4-4 in Figure 3 of the power chair as illustrated generally in Figures 1 through 3, showing a motor, transmission and frame side member in detail in accordance with the preferred embodiment of the invention.

Figure 5 is a rear view of a frame of a power chair as illustrated generally in Figures 1 through 4 in accordance with the preferred embodiment of the invention.

Figure 6 is a broken isometric view taken from the rear of a battery tray in place within a central portion of the frame of a power chair embodying aspects of the invention as illustrated generally in Figures 1 through 5 in accordance with the preferred embodiment of the invention.

Figure 7 is an exploded isometric view of a foldable footrest which is attached to the frame at the front of the power

manually adjustably positioning seat height and/or tilt respecting the frame, without the use of tools, including front and rear seat support members which are longitudinally spaced from one another, extend upwardly from the frame and are movable upwardly respecting the frame independently of one another together with means for manually fixing the front and rear seat support members independently at selected ones of a plurality of positions to the frame.

In yet another of its aspects this invention provides a power chair including a foldable frame, a seat having a cushion, a back and arms on either side of and above the cushion and means for adjustably transversely positioning the arms separated from one another along a continuum of positions thereby to adjustably select the effective width of the seat, where the means for adjustably positioning the arms may include an arm support base, arm support extensions connected to the arm support base and movable transversely therealong and means for adjustably fixing the arm support members respecting the arm support base at a selected location along said continuum of positions along the arm support base by application of manual force thereto without the use of tools.

In yet another of its aspects this invention provides a power chair having a foldable frame and a seat and providing in combination the aforementioned means for manually adjustably positioning seat-tilt respecting the frame without the use of tools.

Brief Description of the Drawings

Figure 1 is a front view of the frame portion of a foldable

power chair including a frame, a seat supported by the frame, a pair of drive wheels rotatable about transverse axes preferably below a central portion of the seat, motors for rotating respective ones of the drive wheels with the motors being preferably connected to the drive wheels for unitary motion therewith and with the frame upon the connected drive wheel encountering an obstacle.

In yet another of its aspects this invention provides a power chair which has a foldable frame, a seat, a pair of drive wheels rotatable about transverse axes preferably below the seat, motors for driving respective ones of the drive wheels, at least one battery for powering the motors and a pair of decorative body fenders for preferably at least partially concealing the batteries and the motors with the fenders preferably resting on the frame. The frame preferably supports the seat by extending through the fenders.

In yet another of its aspects this invention provides a power chair including a foldable frame, a seat, a pair of drive wheels rotatable about transverse axes below the seat, motors for driving respective ones of the drive wheels, at least one battery for powering the motors and means, preferably operable responsively to preferably manually generated force, for releasably connecting the seat to the frame, where the preferably manually generated force is preferably axially oriented and is most preferably in the form of a pair of parallel force vectors.

In yet another of its aspects this invention provides a power chair having a foldable frame, a seat and means for

Summary of the Invention

In one of its aspects this invention provides a foldable, midwheel drive power chair having a frame, a removable seat supported by the frame, a pair of drive wheels connected to the frame and preferably rotatable about a transverse axis under a central portion of the seat and a pair of idler wheels preferably connected to the frame behind the drive wheels.

In another of its aspects this invention provides a foldable midwheel power chair including a frame, a seat and latch means for retaining the seat preferably in fixed disposition on the frame upon application of downward force to the seat such as by a power chair user occupying the power chair seat and for releasing the seat from the frame responsively to application of preferably manually generated and applied preferably axially-oriented force to said latch means, all without use of tools.

In yet another of its aspects this invention provides a foldable midwheel power chair including a frame, a seat preferably having cushion and back portions, with the seat being mounted on the frame, a pair of drive wheels connected to the frame and rotatable about transverse axes below a portion of the seat cushion supporting a chair occupant's thighs, where each drive wheel is rotatably connected to a side member portion of the frame which side member frame portions move towards one another when the power chair is folded after the seat portion has been removed from the foldable frame, where the power chair preferably includes a pair of idler wheels connected to the frame behind the seat.

In yet another of its aspects this invention provides a

conventional power wheelchair to reverse the wheelchair direction by turning the wheelchair around within a corridor or hallway of a conventional office building or most homes.

Power wheelchairs with two drive motors are known; one is illustrated in United States patent 5,540,297. Other power wheelchairs are disclosed in United States patents 4,513,832; 4,538,857; 5,094,310; 5,145,020 and 5,366,037.

Front wheel drive power wheelchairs are sold by Permobile, Inc. in Woburn, Massachusetts and typically have the driving front wheels at the extreme forward end of the vehicle chassis thereby requiring substantial space in order to turn the front wheel drive power wheelchair because the axis of rotation of the chair, upon turning, is between the drive wheel axes which are at the extreme forward end of the chair.

Foldable power rear wheel drive wheelchairs are also known, having been developed by converting conventional folding wheelchairs into powered folding wheelchairs by incorporation of drive motors into the conventional folding wheelchairs. Such conventional folding wheelchairs are typically difficult to fold in that an "X" folding mechanism is utilized having sleeves sliding along tubular members in a vertical direction as the two halves or sides of the folding wheelchair frame move towards one another. The "X" members terminate in the sleeves which slide up and down along vertical members of the side frames. Typically, the sleeves tend to bind as the sleeves endeavor to slide along the vertical members; such binding makes it difficult to fold and unfold conventional folding power wheelchairs.

FOLDABLE POWER WHEELCHAIR

Field of the Invention

This invention relates to wheelchairs, particularly to powered wheelchairs, for use by handicapped and disabled persons.

Background of the Invention

Power wheelchairs are known and have been the subject of increasing development efforts to provide handicapped and disabled persons with independent mobility to assist handicapped and disabled persons in leading more normal lives.

Power wheelchairs known heretofore have, for the most part, resembled conventional, manual wheelchairs; indeed, many such power wheelchairs have merely been conventional wheelchairs equipped with motors. Use of such power wheelchairs sometimes results in the user feeling a stigma associated therewith in that unthoughtful persons may view and even speak to the power wheelchair user in a quizzical or even offensive manner.

Known power wheelchairs suffer in that they tend to be large and are not particularly maneuverable. These large, difficult to maneuver power wheelchairs present difficulties for the power wheelchair user in navigating within conventional dwellings which have not been modified to accommodate such conventional power wheelchairs.

Typical conventional rear wheel drive power wheelchairs, which are little more than manual wheelchairs equipped with motors, have turning circles of about 72 inches in diameter, whereas typical front wheel drive power wheelchairs have, for the most part, turning circles in the neighborhood of 52 inches in diameter. These turning circles are too big for the user of a

received in a selected one of semi-circular bottomed grooves 156 formed in shaft portions 154, as discussed above and as shown in the drawings respecting the forward seat support members 96.

The semi-circular bottom grooves 156 formed in shaft 154 of the rear seat support member are preferably formed facing the rear of the power chair; this provides assurance that the power chair in general and the seat mounting system in particular is properly assembled. If rear seat support member 98 is inserted into longitudinally extending tubular frame member 62 backwards, with axial slot 210 facing towards the rear, rear seat support member 98 cannot be secured in place because pin 158 cannot engage a semi-circular bottomed groove 156 but rather interferes with a solid portion of shaft 154 of rear seat support member 98.

As yet another advantage resulting from the orientation of the semi-circular bottomed grooves 156 formed in shaft 154 of the rear seat support member, seat support members 96, 98 are preferably rigid plastic composite materials, most preferably glass filled nylon. These materials are stronger in compression than in tension. Positioning the forward and rear seat support members 96, 98 in the manner illustrated, with the grooves facing oppositely in the forward and rear seat support members, takes advantage of the higher strength in compression characteristic of the glass filled nylon thereby to provide maximum strength regions in the respective seat support members to resist stresses received when power chair 10 is rapidly decelerated or accelerated while proceeding either forwards or backwards.

To secure seat 14 in position on frame 12, initially an

individual lifts seat 14 first to position circularly cross-sectioned longitudinally extending tubular members 110 of subframe 108 between the upstanding walls of rear seat support member 98 and then to position rear transverse rods 212 in position within forwardly opening longitudinally elongated axial slots 210 as indicated generally by arrow N in Figure BB. This sequence of operation facilitates securing seat 14 in position on frame 12. Initially positioning circularly cross-sectioned longitudinally extending tubular members 110 of subframe 108 between the respective walls of rear seat support members 98 helps to align rear transverse rods 212 in a position to easily engage forwardly opening longitudinally elongated axial slots 210, all as indicated by arrow N in Figure BB. Once rear transverse rods 212 have engaged axial slots 210, rearward force is applied to seat 14, specifically to cushion 20, to slide rear transverse rods into flush engagement with the closed ends or bottoms of the horizontal slots formed in walls 214 of rear seat support members 98.

Once rods 212 are in this position within slots 210, seat 14 may be pivoted downwardly about an axis defined by rear transverse rods 212 in the direction indicated by arrow P in Figure Z.

As seat 14 pivots downwardly about the axis defined by rear transverse rods 212, rods 206 encounter a rounded, downwardly sloped upwardly facing surface 216 of hooking member 100. Surface 216 is so-designated and illustrated in Figures EE, FF and GG. As forward transverse rod 206 bears downwardly on surface 216, the rounded configuration of rod 206 and the rounded

downwardly sloping configuration of surface 216 resolves the force applied by rod 206 due to the weight of seat 14 to produce a force vector on hooking member 100 tending to rotate hooking member 100 in the direction illustrated by arrow A in Figure EE.

As hooking member rotates in the direction indicated by arrow A in Figure EE, tip 152 of hooking member 100 rotates into the position illustrated in phantom lines in Figure EE thereby opening the mouth of the groove indicated by arrow J in Figure EE. This permits forward transverse rod 206 to move downwardly into a position at which forward transverse rod 206 is supported by a horizontal shoulder portion 218 of U-shaped frame 150 of forward seat member 96. This movement in an arcuate direction is indicated by arrow P in Figure Z. Horizontal shoulder surface 218 is illustrated and so-designated in Figures EE and FF. Seat 14 in position with forward transverse rods 206 resting on horizontal shoulder surfaces 218 and engaged with forward seat support members 96 is illustrated in Figure AA.

Once forward transverse rods 206 are resident on horizontal shoulder surfaces 218 and are abutting shoulder surfaces 220 of forward seat and once forward transverse rod 206 has cleared tip 152 of hooking member 100, bias applied to hooking member 100 by spring 102 causes hooking member 100 to rotate clockwise in Figures Y through GG thereby causing open slot J to close over forward transverse rod 206. In this position forward rod 206 is restrained against forward movement by hooking member 100 and against rearward movement by forwardly facing vertical shoulder surfaces 220. Additionally, rear transverse rod 212 is

constrained against rearward movement by the closed bottom of the unnumbered horizontal slot in rear seat support member 98. As a result, seat 14 is securely retained in position, connected by vertical seat support members 96, 98 to frame 12.

As seat 14 pivots about rear transverse rod 212 and moves downwardly as indicated by arrow B in Figure Z, hooking members 110 are received within slots 210 formed in the bottoms of longitudinally extending tubular members 110. The upwardly extending walls 151 of U-shaped frame portion 150 of forward seat support member 96 are, similarly to walls 214 of rear seat support member 98, transversely spaced one from another sufficiently to receive longitudinally extending tubular member 110 therebetween, as depicted generally in Figure CC. Receipt of longitudinally extending tubular members 110 between upwardly extending walls of the rear seat support member assists in alignment of the seat with the seat support members when the seat is being engaged with the seat support members, as described above.

To remove seat 14 from power chair 10, the procedure is reversed. An individual begins by pressing exterior end surfaces 166 to the left in the direction indicated by double ended arrow M in Figures HH and II. This axially applied manual force moves plugs 114 to the left in Figures HH and II, against the restraining force constantly applied by spring 112. As plugs 114 move to the left, those plugs encounter rounded downwardly sloping surfaces 216 of hooking members 100. Continued application of manual force to pushbutton surfaces 166 against force applied by spring 112 causes plugs 114 to push against

hooking members 100, causing hooking members 100 to rotate counter-clockwise as viewed in Figures CC through EE, thereby causing tips 152 to rotate upwardly and thereby causing open slot J to assume a position where it is opening slightly upwardly, as illustrated in phantom lines in Figure EE.

At this position the forward ends of longitudinally extending tubular members 110 may be lifted since forward transverse rods 206 are no longer restrained against vertically upward movement by hooking members 100. Hence seat 14 may be moved upwardly in a pivotal fashion about a pivot defined by rear transverse rods 212, with seat 14 moving in a direction opposite that indicated by arrow P in Figure Z. Once seat 14 has been rotated somewhat in a direction opposite to that by arrow P in Figure Z, seat 14 may be moved horizontally, to the right viewing Figure Z, thereby disengaging rear transverse rods 212 from the horizontal forwardly facing open slots formed in walls 214 of rear seat support members 98.

Figure T illustrates structure providing means for adjustably transversely separating by positioning arms of seat 14 where the arms are designated generally 182 with the left (looking forward) arm designated 182L and the right (looking forward) arm designated 182R. The structure facilitating adjustable transverse separation and positioning of arms 182L, 182R includes an arm support base 184 which is preferably a hollow rectangular cross-section tubular member. Arm support base 184 is connected to seat 14, specifically to cushion portion 20 thereof, indirectly.

Specifically, arm support base 184 is connected to

rearwardly facing portions of L-shaped brackets 222, the lateral portion of one of which is visible in Figures Y through CC and is partially visible in Figure T. The portion of L-shaped bracket 222 which faces rearwardly and is preferably in facing contact with a rearwardly facing surface of cushion portion 20 of seat 14 is not visible in Figure T; it is hidden behind the hollow rectangular cross-section tubular member defining arm support base 184. Lateral portions of L-shaped brackets 222 are connected, preferably by welding, to cushion support brackets 224 which are secured to cushion portion 20 of seat 14 and are illustrated in Figures Y through CC. More preferably L-shaped brackets 222 are secured to lateral flange portions of cushion support brackets 224 via a pair of Phillips head screws illustrated in Figures Y through CC but not numbered to aid clarity of the drawings.

Cushion support brackets 224 preferably include upstanding portions which run along the longitudinally extending side surfaces of seat cushion 20 and bottom portions which run longitudinally along the bottom surface of seat cushion 20. Cushion support brackets 224 are preferably secured to cushion portion 20 of seat 14 via screw-type fasteners driven into the bottom of seat cushion portion 20 through apertures in the bottom longitudinally extending portions of cushion support brackets 224.

A seat back support bracket 226 illustrated in Figure T and Figures Z through CC is of generally L-shaped cross-section and includes a rearwardly facing flange portion and a side facing flange portion. The rearwardly facing flange portion includes

apertures therethrough for screw-type fasteners to pass through and into the rearwardly facing surface of seat back 22, to secure seat back 22 to the associated seat back support bracket 226.

Seat back support brackets 226 are preferably connected to seat cushion support brackets 224 via a single rivet connection at each side of seat cushion and back portions 20, 22; the single rivet connection is somewhat visible in Figures Z through CC. The single rivet connection is partially hidden by a portion of the arm support structure, specifically a vertically extending arm support member 190 in Figures Z through CC. The single rivet connection between seat back support brackets 226 and seat cushion support brackets 224 facilitates folding or pivoting movement of seat back 22 towards seat cushion 20 about the points of single rivet connection between cushion support brackets 224 and seat back support brackets 226.

Arm support extensions are designated generally 186 in Figure T and include horizontal supports 188 and vertically extending supports 190. Arm cushions 192 are pivotally connected to vertical supports 190 for arcuate motion of arm cushions 192 with respect thereto.

Arm support base 184 includes a pair of tapped holes, not illustrated in Figure T, which receive in complemental threaded engagement threaded shaft portions which are fixed to hand knobs 194, illustrated in Figure T. The threaded shafts affixed to knobs 194 when advanced or retracted by rotation of knobs 194, through complemental engagement of the threaded shafts with the tapped holes in arm support base 184, move against or retract from contact with respective horizontal arm support portions 188

of arm support extensions designated generally 186, which are associated with left and right arms 182L, 182R.

Frictional contact between the threaded shafts fixedly connected to knobs 194 and respective horizontal arm support portions 188 fixes arm support extensions 186 in position when the threaded shafts are tightly turned thereagainst. Fixation of arm support extensions 186 in position fixes the position of arms 182L, 182R. Since horizontal arm supports portions 188 are movable into and out of arm support base 184, arms 182L, 182R and arm cushions 192 may be manually moved between the positions illustrated in solid lines in Figure T and the positions illustrated in dotted lines in Figure T, thereby adjusting effective width of seat 14 of power chair 10.

Knobs 194 are rotated by application of manual force thereto. Once the knobs are rotated to a position at which threaded shafts associated therewith only lightly contact or do not even contact horizontal arm support portions 188, these horizontal arm support portions may be moved by hand, thereby adjusting transverse separation of arm cushions 192 and hence the effective width of seat 14, all without use of tools.

Figure 8 illustrates structure providing adjustable width for the frame of the back of a seat, in an embodiment different from that illustrated in Figures Y through II, usable with foldable power chair 10. A back frame 424 has adjustable width substantially vertical rails 426. Adjustable width vertical rails 426 are equipped with tubular extensions 428 at their bases where rails 426 meet a seat frame 430. Tubular extensions 428 have vertical bores 432 formed through them. The adjoining seat

frame 430 has extending hollow tubular extensions 436 where the seat frame 430 attaches to the adjustable width vertical rails 426 of back frame 424. Hollow tubular extensions 436 have corresponding vertical bores 434 through them. Tubular extensions 428 of adjustable width vertical rails 426 fit inside hollow tubular extensions 436 of seat frame 430. A pin is inserted into the aligned bores after the vertical rail tubular extensions 428 are inserted into the hollow tubular extensions 436 of the seat frame 430 as shown in Figure 8. Either of the two tubular extensions 428 extending forward from the mounting block portion of the back frame 424 illustrated in Figure 8 may be inserted into tubular extension 436 of seat frame 430. Similarly, at the opposite side of seat frame 430, either of two tubular extensions 428 may be inserted into the corresponding seat frame hollow tubular extension. By selecting one of the tubular extensions 428 to be inserted into seat frame hollow tubular extensions 436, this provides a range of widths for the seat back frame 424.

As illustrated in Figures 16 and 17, the back of the frame of the seat for the foldable power chair 10 may be folded from the upright position to a folded position for facile transport of seat 14 when seat 14 has been removed from power chair 10 prior to folding of the power chair frame.

Adjustable width vertical rails 426 forming a portion of back frame 424 have mounting blocks 506 forming a lower end of each vertical rail 426. Vertical rail tubular extension 428 extend forwardly from mounting blocks 506. Mounting blocks 506 preferably have two portions; a lower portion 506L and upper

portion 506U where these two portions may be machined from separate pieces of metal and then joined by welding, bolts or other fastening means.

Pivotally connected to mounting block 506U is a tubular receptacle 508 within which a lower extremity of vertical rail tubular extension 428 resides, all as illustrated in Figures 16 and 17. Affixed to the exterior of tubular receptacle 508 is a sleeve 510 to which is affixed an axially extending plate 512. In the construction illustrated in Figures 16 and 17, plate 512 is secured to sleeve 510 by a set screw 514. Set screw 514 passes through sleeve 510 and not only connects plate 512 to sleeve 510 but secures the assembly of plate 512 and sleeve 510 against movement axially along the exterior of tubular receptacle 508.

A pair of slots, preferably formed by machining, are in mounting block 506U for receipt of axially extending plate 512. One of these slots, designated 516 in Figures 16 and 17, receives plate 512 when seat back frame 424 is to be positioned upright, as illustrated in Figure 16, for a user of the foldable power chair to be seated therein. A second slot 518 formed in mounting block 506U receives an axial extremity of axially extending plate 512 when the seat back frame 428 is in the folded position, with the seat back essentially parallel with the seat cushion, for transport as illustrated in Figure 17. Seat back frame 424 pivots respecting mounting block 506U about pivotal connection 520 illustrated in Figures 16 and 17. A knob 448 has affixed thereto a threaded shaft, not number in the drawings, and threadedly engages a threaded bore 522. The bore 522 is

positioned so that knob 448 and the threaded shaft attached thereto abuttingly contact the axial extremity of axial extending plate 512 when the seat back frame is in the upright position illustrated in Figure 16 and interferes with the axial extremity of axially extending plate 512 thereby precluding rotation of seat back frame 424 about pivotal connection 520 when the seat back frame is in the position illustrated in Figure 17.

To move the seat back frame from the position illustrated in Figure 16 to the position illustrated in Figure 17 set screw 514 is loosened, knob 448 and the shaft associated therewith is loosened and sleeve 510 is moved slidably along the tubular receptacle 508 to disengage axially extending plate 512 from first slot 516. Once this has been accomplished, the seat back frame may be pivoted about connection 520 from the position illustrated in Figure 16 to the position illustrated in Figure 17. At that position, sleeve 510 is moved to the right in Figure 17 thereby causing axially extending plate 512 to enter second slot 518 illustrated in Figure 17 whereupon set screw 514 may be tightened, knob 448 may be put into position and interference between the threaded shaft attached to knob 448 and axially extending plate 512 precludes rotation of seat back frame 428 about pivotable connection 520 thereby retaining seat back frame 428 in the folded position for transport of the seat separate and apart from the foldable power chair base.

As illustrated in Figures 16 and 17, back frame 424 of the seat folds downward until it is parallel to seat frame 430 which allows the seat to be removed as a unit and carried away.

As illustrated in Figures Z through II, arm 192 includes an

arm cushion portion 242 which is preferably upholstered to provide cushioning for the arms of the user of power chair 10. Arm cushion portion 242 is mounted on a longitudinally elongated support web 244. Arm cushion portion 242 and longitudinally elongated arm cushion support web 244 together constitute an arm 182 of power chair 10.

Support web 244 has a horizontally oriented central portion on which arm cushion portion 242 is supported and two vertically extending webs, which are visible in Figure T. Two webs 246 may be of different size and shape with one of webs 246 supporting joystick controller 196 and the electronics associated therewith and the remaining web 246 being of more tapered, somewhat truncated shape. Web 246 supporting joystick 196 and the associated electronics is denoted 246J in the drawings.

Affixed to the lower longitudinal extremity, preferably by welding, of vertical support portion 190 of arm support extension 186, is a mounting block 248, as illustrated in Figures JJ and KK. Mounting block 248 preferably has a tapped hole therein. Residing within the tapped hole is a bolt threadedly engaging the tapped hole where the bolt is designated 250 in Figures JJ and KK. Bolt 250 can be advanced into or withdrawn from the tapped hole in mounting block 248 thereby to vary the length of bolt 250 protruding from mounting block 248.

Arm 192 connects to vertical support portion 190 via a pivotal connection provided by a single rivet indicated as 252 in Figures JJ and KK.

As is apparent from Figures JJ and especially from Figure KK, vertical webs 246, 246J of longitudinally elongated arm

cushion support web 244 are spaced apart to receive the extremity of arm vertical support portion 190 therebetween. Mounting block 248 is preferably of the same width, measured transversely to the plane of the paper, as vertical arm support portion 190. Hence mounting block 248 and bolt 250 may fit easily slidably between webs 246, 246J of arm 182.

Referring to Figure JJ, when arm 182 is pivoted downwardly about the pivotal connection provided by rivet 252, in the direction indicated by double ended arrow S, the central portion of longitudinally elongated arm cushion support web 244 contacts the head of bolt 250 and cannot move further arcuately downwardly as a result of such contact. Adjustment of the position of bolt 250, specifically by rotating and advancing bolt 250, into or out of mounting block 248, adjusts the angle at which arm 182 and specifically the central portion of longitudinally elongated arm cushion support web 244 contacts bolt 250. This facilitates adjustment of the angular position of arm 182 relative to the remainder of seat 14 when arm 182 is positioned at the limit of its arcuate downward travel in the direction of double ended arrow S in Figure JJ.

As illustrated in Figure 9, a patient transfer device 440 provides a smooth slidable surface via which to relocate a patient easily from foldable power chair 10 to another location. Patient transfer device is an alternative to the seat structure illustrated in Figures Z through JJ. Patient transfer device 440 includes an adjustable planar member, with a smooth, sliding surface, attached to frame 12 of foldable power chair 10, permitting a patient to slide from the chair to another

location.

A patient transfer board 441 connects by a hinge 442 to a patient transfer mounting board 444. The patient transfer mounting board 444 is in turn fixed, preferably by welding, to longitudinally extending member 62 of the frame 12 of the foldable power chair 10.

A spring loaded lever is preferably attached to the back side of patient transfer board 441, allowing the patient or an attendant to rotate patient transfer board 441 to a vertical position and maintain the board at that position. Thus, patient transfer board 441 may be rotated up to a vertical position or down to a horizontal position about hinge 442. Additionally, patient transfer board 441 may rotate even lower about hinge 442 to provide a more or less continuous surface from where the patient is seated on the power chair to the location in which the patient is to be moved. Hinge 442 is preferably equipped with a detent of increasing resistance so that when the patient or an attendant moves patient transfer board 441 into the desired position, the transfer board stays at that position until released. Once released by movement towards a vertical position about hinge 442, the spring loaded lever pulls the transfer board back into the vertical position. After patient transfer board 441 is released, the spring loaded lever pulls it back up into the vertical position.

The patient transfer board 441 and patient transfer mounting board 444 are preferably upholstered; this has not been depicted in the drawings. The upholstery is preferably maintained in place on the patient transfer device 440 by mating pads of

respective hook and eye fabric material, such as that sold under the trademark Velcro, affixed to upwardly facing surfaces on the patient transfer board 441 and patient transfer mounting board 444.

Arm rests for the foldable power chair 10 are preferably vertically adjustable. One preferred embodiment apparatus facilitating vertical adjustment of the arm rests of foldable power chair 10 is depicted in Figures 10 and 11. In those drawings, an arm rest 182, which may be either a left arm rest or a right arm rest, is connected to a machine member 452 which has longitudinally aligned depressions machined into its surface. Depressions 454 are preferably aligned along the longitudinal length of machine member 452 and are located at the transverse midpoint thereof, as illustrated in Figures 10 and 11.

Machine member 452 is received by a slot 554 formed in an arm rest box 456. The left and right arm rests 182 are preferably connected to an arm rest machine member 452 which has depressions machined into its surface. An arm rest box 456 with a removable knob 458 protruding from its outwardly facing surface arm rest machined member 452; arm rest box is preferably fixedly connected to frame 12.

The arm rest machine members 452 are welded onto the frames of the left and right arm rests 182. The arm rest machine members 452 have two machined depressions on their laterally outwardly facing surfaces. The arm rest box 456 has a round knob 458 on its lateral surface. The inside of the knob 458 has a semi-circular groove of varying depth in which resides a ball bearing 556. Ball bearing 556 fits into one end of a semi-

circular varying depth groove of the knob 458 of the arm rest box 456. The remaining portion of the elongated semi-circular groove, in which ball bearing 556 does not fit, is shallower than the area where the ball bearing fits.

As the knob 458 of the arm rest box 456 is turned, the ball bearing moves into the depressions on the surface of the arm rest machined member 452. When the ball bearing fits into one of the depressions, the arm rest 182 cannot be moved vertically. When it is desired to adjust one of the arm rests 182 upwardly or downwardly, knob 458 of arm rest box is turned through perhaps one quarter of a turn. Due to the configuration of the elongated semi-circular groove formed in the interior facing circular surface of knob 458.

Forward anti-tip wheels 42 do not normally contact the ground or other surface on which power chair 10 operates. Forward anti-tip wheels 42 are maintained above the ground and provide protection against tipping in the event of forward pitching of power chair 10 due to encounter with an obstacle, traverse of a significant downgrade and the like. The off-the-ground, anti-tip positioning of wheels 42 is illustrated in Figure N.

Anti-tip idler wheels 42 are connected to frame 12 via a spring-strut combination which is designated generally 44 in the drawings, specifically in Figures N and U through X. Each spring-strut combination 44 includes a U-shaped spindle 228; one leg (of the U-shape) of one of spindles 228 is shown in side view in Figure N. The U-shape of spindles 228 is readily apparent from Figure P.

One arrangement of the U-shaped spindle apparatus is illustrated in Figures N and U though X; another and preferred arrangement of the U-shaped spindle apparatus as illustrated in Figures 1, 2 and 18 through 20.

U-shaped spindles 228 are preferably fabricated by welding rectangular cross-section tubular stock between two parallel plates with the tubular stock forming the base of the U. Spindles 228 are preferably pivotally connected to frame 12 preferably using screw-bolt assemblies. The side plate portions of spindles 228 fit pivotally on either side about the lower portions of respective downwardly extending vertical members 66, which are illustrated in Figures S and U through Y. The nut and bolt pivotal connections of U-shaped spindles 228 to vertical members 66 are depicted schematically by indicator numeral 230 in Figures U through Y and are also visible in Figures 4 and 5 and are depicted schematically in Figure 14.

Extending between the legs of U-shaped spindles 228 are transverse shafts 238. Mounted on transverse shafts 238, via passage of transverse shafts 238 through bores formed therein, are cylindrical spring support bases 236.

Secured to and extending from cylindrical spring support bases 236 are upstanding struts 238, the upper extremities of which extend through and are slidably retained within fittings which are resident within apertures, which have not been numbered in the drawings, formed in horizontally extending planar portions of forwardly extending pedestals 202, which are visible in Figure S as well as in Figures U through X. One of upstanding struts 238 has been identified by a lead line extending to the vertical

extremity thereof in Figures W and X.

Preferably, the aperture in pedestal 202 through which shaft 238 passes is longitudinally elongated and formed as a slot, rather than a circular hole. Additionally, springs 236 are preferably retained in position by respective bushings illustrated in Figures 18 through 20 and designated generally 522. Each bushing 522 fits at the top of a spring 236 with the upper portion of bushing 522 contacting the downwardly facing surface of pedestal 202.

Bushing 522 includes a vertical strut passageway 524 for passage therethrough of an upstanding strut 238. Bushing 522 further includes a pair of shoulder bolt-receiving bores 526 which are transverse to vertical strut passageway 524 and are formed in a barrel-shaped upper portion 528 of bushing 522, as illustrated in Figures 18 and 20.

A conical portion 530 of bushing 522 extends downwardly from barrel-shaped portion 528 and fits within coil spring 236. When an associated anti-tip wheel comes up, for example upon encountering a curb, the spring-strut assembly moves forward and tilts, with the strut 238 and spring 236 becoming more horizontal and less vertical. This pivoting action of the spring-strut is facilitated by the rounded outer surface of barrel-shaped portion 528 of bushing 522 contacting the downwardly facing surface of pedestal 202 thereby facilitating rotation of the spring-strut assembly relative to pedestal 202. This rounded configuration of barrel-shaped portion 528 facilitates a very low friction contact between bushing 522 and the lower surface of pedestal 202. Bushing 522 is retained in place by shoulder bolts

extending between outer surfaces of pedestals 202 and residing in shoulder bolt receiving bores 526.

Upstanding shaft 238 extends all the way up from the lower member through the spring, through bushing 522, through the longitudinally elongated slot in pedestal 202 and is retained in place by a nylon washer and a bolt engaging the upper portion of shaft 238.

With this arrangement, upon an anti-tip wheel 42 encountering an obstacle or upon power chair 10 pitching forwardly as depicted schematically in Figure X, anti-tip wheels 42 move arcuately, together with U-shaped spindle 228, as they pivot about pivotal connection 230 relative to frame 12. This pivotal motion is denoted by double ended arrow Q in Figure X. As the illustrated anti-tip wheel 42 and U-shaped spindle 228 pivot about connection point 230, upward movement of spindle 228 causes distance between the anti-tip wheel 42 and pedestal 202 to decrease, thereby compressing spring 236 in the direction indicated by double ended arrow R in Figure X.

Compression of spring 236 provides a cushioning effect when anti-tip wheels 42 contact an obstacle or contact the ground due to forward pitching of power chair 10 as illustrated schematically in Figure X. The suspension of anti-tip wheels 42 provided by spring-strut combination 44 connects anti-tip idler wheels 42 to frame 16 for arcuate upward motion relative to frame 12 upon tipping of power chair 10 or contact of anti-tip wheels 42 with an above-grade obstacle.

A nut 240 mounted on the threaded portion of strut 238 extending above pedestal 202 permits selectable compression of

spring 236 thereby providing adjustment of the spring force applied to anti-tip second idler wheels 42 to resist arcuate upward movement thereof upon forward tipping of power chair 10 or upon wheels 42 encountering an obstacle. Rotation of nut 240 also adjusts the distance at which wheels 42 are from the ground.

The tight maneuverability feature of the power chair achieved by locating the drive wheels, which are front wheel drive wheels, close to the longitudinal center of the power chair, while having many attendant advantages as described above, has a minor disadvantage in that there is a slight tendency to tip if a significant obstacle is encountered when the chair is decelerating or traveling forwardly downhill.

Any slight tendency towards forward tipping is counteracted by the spring loaded anti-tip wheels 42 located in front of each drive wheel 16. Spring loading of anti-tip wheels 42 is accomplished via springs forming portions of spring-strut combinations 44 biasing anti-tip wheels 42 downwardly towards the ground. When choosing the rate for these springs used in connection with anti-tip wheels 42, compromise is required between a spring rate stiff enough to resist forward tipping upon deceleration of the power chair yet light enough to allow the power chair to overcome minor obstacles such as incline transitions, curves or other uneven terrain.

An important feature provided in the power chair is that the pairs of transverse members 402 of upper forward transversely extending foldable member 64 and the pair of transverse members 404 of lower forward transversely extending foldable member 68

are angled below horizontal in the unfolded condition of the chair. This prevents inadvertent collapse or folding of the chair.

There are stops provided at the pivotal connection between upper members 402 and vertically oriented beam 412 and at the pivotal connections of lower transverse members 404 with vertically oriented beam 412. As a result of these stops, members 402, 404 cannot pivot further downwardly from the operating position illustrated in Figure 1. As a result of the presence of these stops, the only way the chair frame can fold is for members 402, 404 to pivot upwardly about their pivotal connections with forward upper and lower transverse fixed beam members 406, 408. However, such upward pivoting cannot occur when the seat is in place on the frame. Presence of the seat supported by the rigid seat frame and carried by seat supports 96, 98 prevents any lateral movement of the side members 460, 462 and, accordingly, prevents any upward rotation of pairs of transverse members 402, 404 respectively forming parts of cross-members 64, 68.

When the chair frame is in the unfolded condition, pairs of transverse members 402 and 404 forming parts of members 64 and 68 pivot about their pivotal connections with upper and lower front fixed transverse beam members 406, 408 to an orientation below horizontal and illustrated in Figure 1. Locking bar 400 is pivotally connected to one of front lower transverse fixed beam members 408 inboard of vertical frame member 66. Downward facing notches formed in locking bar 400 engage pins extending forwardly from vertically oriented central connecting member 412.

and from member 402 positioned oppositely from the point of connection of locking bar 400. With locking bar 400 in place and the slots in locking bar 400 engaging pins extending forwardly out of one of transverse members 402 and vertically oriented beam 412, locking bar 400 secures the foldable frame in an open position in which the frame cannot be folded without disengaging locking bar from those pins.

In the preferred embodiment width of the foldable power chair measured from the outer extremities of the two drive shafts in the unfolded condition is 23-1/2 inches. When the foldable power chair is folded, the width of the chair measured between the outer extremities of the two drive shafts is 13-1/2 inches.

One of the important features provided by the foldable power chair is the accommodation of a rigid seat on a folding chair base. Known folding power chairs use sling-type seats which are similar to "directors' chairs" widely used by consumers.

In sling-type seats, the seat portion, which is cloth, folds as the power chair frame is folded. Such cloth or fabric seats which fold as the power chair frame is folded are less than desirable from the standpoint of providing stability for the power chair user's pelvic region, which may be in need of rehabilitation therapy.

Contrasting, the flat form rigid base seat used in connection with the power chair of the invention provides a stable platform for the power chair user's pelvis, thereby facilitating rehabilitation therapy.

Another disadvantage of the sling-type seat in a folding

power chair is that the sling-type seat does not contribute rigidity to the folding power chair. In known conventional folding power chairs with sling-type seats, there is a certain amount of wobble that is inherent in the chair. Such wobble is eliminated with a rigid seat structure such as incorporated by the foldable power chair of the invention.

Yet another advantage of the foldable power chair disclosed herein is that, in contrast to conventional folding power chairs, there is a substantial reduction in height of the power chair unit when the power chair unit is disassembled and folded. In conventional folding power chairs using sling-type seats, the seat support members, particularly the uprights, typically do not fold downwardly.

Contrasting, in the power chair as disclosed herein, with the seat removed, the chassis is only 20 inches high. The length of the chassis is 34-1/2 inches.

A major advantage afforded by the power chair as disclosed herein is the ease of folding of the power chair when the leash is attached to forward and aft portions of the frame as illustrated in Figure 1 and lifted upwardly, the chair folds easily with the two side members 402, 404 moving easily towards one another due to the downward force of gravity which resolves itself to urge the two side members 402, 404 towards one another.

The lifting action provided by the strap facilitates the folding of the chair because as the user pulls upwardly on the strap, he reduces the downward force applied from the wheels to the ground and effectively may lift the chassis off the ground.

where the chassis then just folds up quite easily. There is no significant sliding resistance resulting from the wheels dragging across the ground. That is a significant advantage over the other foldable chairs where once the seat is taken off, there still is significant effort required.

A major advantage that the connections between the frame members are pivoting connections about clevis pins that are driven through clearance holes in the frame members. Preferably, there are no sliding connections between frame members in the power chair structure.

Figure 12 illustrates a parallelogram linkage 536 with one bar of the linkage being defined by a support plate 540 adapted to be connected to the frame or arm rest of the power chair and with the opposite bar of the linkage defined by a support plate 538 for the joystick controller for the power chair. The parallelogram linkage 536 facilitates movement of the joystick controller from a position ahead of the arm rest, identified by arrow A in Figure 12, to a position adjacent to the side of the arm rest, identified by arrow B in Figure 12, with the orientation of the joystick remaining at all times fixed with respect to the longitudinal axis which is the direction of travel of the power chair.

This maintenance of constant orientation of the joystick is important so that no matter what the position of the joystick controller within the range of movement provided by the parallelogram linkage, movement of the joystick in the forward, longitudinal direction by the power chair occupant causes the power chair to travel forwards. If the parallelogram linkage 536

was not used, the orientation of the joystick controller relative to the longitudinal direction would change within the range of motion provided by the relevant linkage. As a result, at some position within that range, movement of the joystick in the forward, longitudinal direction would cause the power chair to travel in a direction skew to the longitudinal. This could be very disturbing and disorienting to the power chair occupant, especially to a power chair occupant having diminished mental capacity.

Figure 22 illustrates the arm rest releasable height adjustment and locking mechanism in position on a power chair while Figures 10 through 11 illustrate the releasable arm rest height adjustment and locking mechanism in various orientations and degrees of disassembly. The arm rest releasable height adjustment and locking mechanism is designated generally 542 and preferably includes a box-like member 456 having a knob 458 rotatably mounted thereon for turning a circular insert facing onto an exposed interior surface of box-like member 456.

An interior surface of the circular insert, which faces the exposed interior surface of the box-like member, is machined to provide a variable depth pocket or groove receptacle 560 receiving a ball 556 which resides in a clearance hole in a wall of box-like member 456, which clearance hole is covered by the circular insert when the releasable locking mechanism is assembled. Dimensions of the machining are such as to make ball 556 protrude from the clearance hole into a vertical passageway through the box-like member when a portion of the interior surface of the circular insert which does not have the variable

depth pocket or groove receptacle 560 formed therein is over the clearance hole. In this configuration, the protruding ball engages one of the depressions machined into member 452 to which the arm rest is attached, and retains member 452 and arm rest against movement. The ball 556 does not substantially protrude from the clearance hole into the vertical passageway through the box-like member when a portion of the interior surface of the circular insert which has the variable depth pocket or groove receptacle 560 formed therein is over the clearance hole. In this configuration, the ball does not protrude sufficiently to engage any of the receptacle depressions 454 machined into a machine member 452 to which the arm rest is attached, and, as a result, the machine member and arm rest are freely moveable relative to releasable locking mechanism 542.

Preferably a knob is provided and connected to the circular insert to facilitate rotation of the circular insert between the positions at which the fixed against movement and is freely movable relative to box-like member 456. With this arrangement, very little torque on the knob is required to move the circular insert between the positions of interest; this is important since many of the users of the power chair can be expected to lack significant strength in their arms, hands and fingers.

Figure 13 illustrates a front view of the frame for an adjustable width power chair, made by modifying the foldable frame illustrated above. In Figure 13, a pair of upper and lower telescoping tubular members extend laterally from respective vertical members 66, with the upper telescoping tubular members being designated 550 and 552 and the lower telescoping tubular

members being designated 554 and 556. Pin connections are provided to secure upper and lower telescoping tubular members 550, 552 and 554, 556 together, at a selected one of a continuum of positions. A single transversely extending telescoping member is preferably used at the rear of the frame. With this arrangement, the power chair, while not foldable for transport, has adjustable width and is especially well suited for accommodating a child as the child grows. Other than substitution of the transversely extending telescoping members 550, etc. for the pivoting members 404, etc., the adjustable width frame and the resulting adjustable width power chair is as described for the folding version of the power chair.

The following is claimed:

1. A power chair comprising:

   a. a frame transversely foldable between operating and transport positions;

   b. a seat connected to said frame;

   c. a pair of drive wheels connected to said frame and rotatable about transverse axes below a portion of said seat supporting an occupant's thighs;

   d. motors for driving respective drive wheels, respective motor/drive wheel combinations being pivotally connected to said frame;

   e. at least one ground-engaging idler wheel connected to said frame and located rearward of said drive wheels; and

   f. at least one anti-tip wheel forward of said drive wheels and positioned above ground, connected to said frame for movement relative to said frame upon encountering an obstacle.

2. The power chair of claim 1 further comprising spring-strut assemblies for resiliently resisting upward movement of said anti-tip wheels upon encountering an obstacle.

3. The power chair of claim 2 wherein said spring-strut assemblies further comprise:

   a. a strut connected to said anti-tip wheel and moveable upwardly therewith;

   b. a spring coiled about said strut;

c. means connected to said frame for constraining an upper end of said spring against upward movement while permitting slidable upward passage of said strut therethrough including a shaft portion slidably receiving said strut and fitting within the interior of said spring and a cap portion connecting with an upper portion of said shaft portion, having a curved exterior upper surface facilitating relative rotary motion of said constraining means respecting said frame responsively to an associated anti-tip wheel encountering an obstacle, upwardly displacing said strut and compressing said spring.

4. The power chair of claim 1 wherein said frame has a pair of rigid parallel side members connected by a plurality of cross members each comprising a plurality of pivotally connected links.

5. The power chair of claim 4 wherein said cross members are transverse to said side members and said pivotal connections rotate about longitudinal axes.

6. The power chair of claim 1 wherein said seat further comprises a pair of transversely spaced arms positioned on respective sides of said and said power chair further comprises means connected to said frame for adjustably positioning said arms at a plurality of heights, comprising:

a. a tongue member fixedly connected to said arm, having a plurality of recesses in the surface thereof;

b. a housing member connected to said frame and having a receptacle of varying depth formed therein, being movable among positions at which various parts of said receptacle having different depth communicate with a selected one of said recesses; and

c. movable means resident in said receptacle and being of size for receipt of a portion thereof by a recess with which said receptacle is communicating for interfering with movement of said tongue relative to said housing when said movable means is in a relatively shallow portion of said receptacle and freely permitting movement of said tongue when said movable means is in a relatively deep portion of said receptacle.

7. The power chair of claim 1 further comprising:

a. manually actuable stick means for controlling speed and direction of power chair motion; and

b. linkage means supportingly connecting said control stick means to said frame and permitting movement thereof between at least two positions while maintaining a fixed orientation relative to a longitudinal axis of said power chair.

8. The power chair of claim 1 wherein said seat includes a generally horizontal occupant vertical support portion and said power chair further comprises:

a. an occupant transfer board pivotally connected to said frame and movable between positions generally parallel and skew respecting said occupant vertical support portion.

9. The power chair of claim 8 wherein said parallel position is co-planar with said occupant vertical support portion and said skew position is generally perpendicular to aid occupant vertical support portion.

10. The power chair of claim 9 further comprising:

a. resilient means for biasing said transfer board towards one of said parallel and skew positions; and

b. detent means for retaining said transfer board at a selected position intermediate said parallel and skew positions in opposition to said resilient means.

11. A power chair comprising:

a. a frame transversely foldable between operating and transport positions;

b. a seat connected to said frame;

c. a pair of drive wheels connected to said frame and rotatable about transverse axes below a portion of said seat supporting an occupant's thighs;

d. motors for driving respective drive wheels, respective motor/drive wheel combinations being pivotally connected to said frame;

e. at least one ground-engaging idler wheel connected to

said frame and located rearward of said drive wheels; and

f. at least one anti-tip wheel forward of said drive wheels and positioned above ground, connected to one of said motors for pivotal movement therewith relative to said frame responsively to changes in drive wheel velocity.

12. The power chair of claim 11 further comprising spring-strut assemblies for resiliently resisting upward movement of said anti-tip wheel upon encountering an obstacle.

13. The power chair of claim 12 wherein said spring-strut assemblies further comprise:

a. a strut connected to said anti-tip wheel and moveable upwardly therewith;

b. a spring coiled about said strut;

c. means connected to said frame for constraining an upper end of said spring against upward movement while permitting slidable upward passage of said strut therethrough including a shaft portion slidably receiving said strut and fitting within the interior of said spring and a cap portion connecting with an upper portion of said shaft portion, having a curved exterior upper surface facilitating relative rotary motion of said constraining means respecting said frame responsively to an associated anti-tip wheel encountering an obstacle, upwardly displacing said

strut and compressing said spring.

14. The power chair of claim 13 wherein said frame has a pair of rigid parallel side members connected by a plurality of cross members each comprising a plurality of pivotally connected links.

15. The power chair of claim 14 wherein said cross members are transverse to said side members and said pivotal connections rotate about longitudinal axes.

16. The power chair of claim 15 wherein said seat further comprises a pair of transversely spaced arms positioned on respective sides of said and said power chair further comprises means connected to said frame for adjustably positioning said arms at a plurality of heights, comprising:

a. a tongue member fixedly connected to said arm, having a plurality of recesses formed in the surface thereof;

b. a housing member connected to said frame and having a receptacle of varying depth formed therein, being movable among positions at which various parts of said receptacle having different depth communicate with a selected one of said recesses; and

c. movable means resident in said receptacle and being of size for receipt of a portion thereof by a recess with which said receptacle is communicating for interfering with movement of said tongue relative to said housing

when said movable means is in a relatively shallow portion of said receptacle and freely permitting movement of said tongue when said movable means is in a relatively deep portion of said receptacle.

17. The power chair of claim 11 further comprising:

a. manually actuable stick means for controlling speed and direction of power chair motion; and

b. linkage means supportingly connecting said control stick means to said frame and permitting movement thereof between at least two positions while maintaining a fixed orientation relative to a longitudinal axis of said power chair.

18. A power chair comprising:

a. a frame transversely foldable between operating and transport positions;

b. a seat connected to said frame;

c. a pair of drive wheels connected to said frame and rotatable about transverse axes below a portion of said seat supporting an occupant's thighs;

d. motors for driving respective drive wheels, respective motor/drive wheel combinations being pivotally connected to said frame;

e. at least one ground-engaging idler wheel connected to said frame and located rearward of said drive wheels; and

f. at least one anti-tip wheel forward of said drive

wheels and positioned above ground, connected to said frame for movement relative to said frame upon encountering an obstacle.

g. spring-strut assemblies for resiliently resisting upward movement of said anti-tip wheel upon encountering an obstacle, comprising:

i. a strut connected to said anti-tip wheel and moveable upwardly therewith;

ii. a spring coiled about said strut;

iii. means connected to said frame for constraining an upper end of said spring against upward movement while permitting slidable upward passage of said strut therethrough including a shaft portion slidably receiving said strut and fitting within the interior of said spring and a cap portion connecting with an upper portion of said shaft portion, having a curved exterior upper surface facilitating relative rotary motion of said constraining means respecting said frame responsively to an associated anti-tip wheel encountering an obstacle, upwardly displacing said strut and compressing said spring;

wherein said frame has a pair of rigid parallel side members connected by a plurality of cross members each comprising a plurality of pivotally connected links;

wherein said cross members are transverse to said side members and said pivotal connections rotate about longitudinal axes.

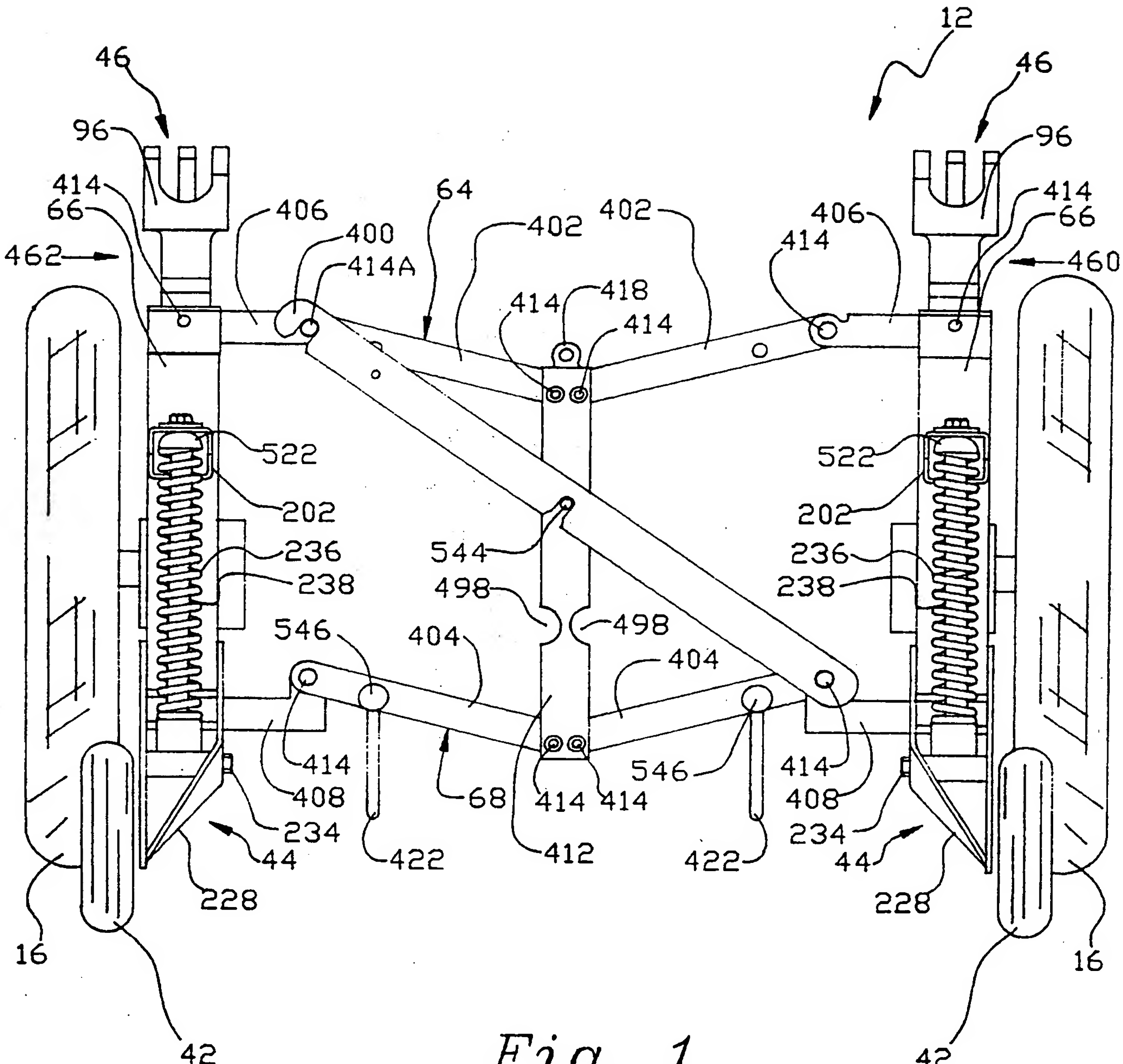

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Fig. 1

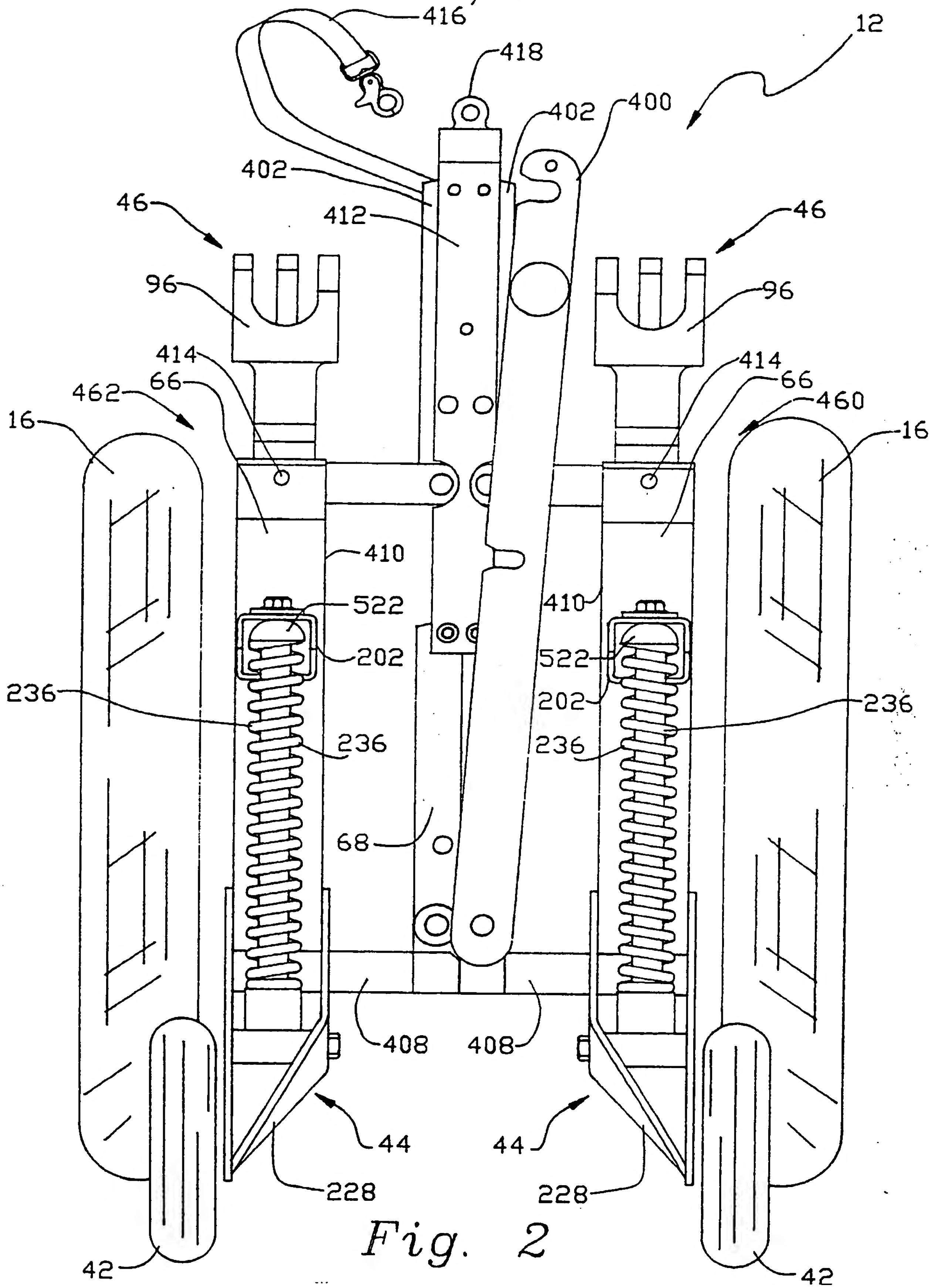
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Fig. 2

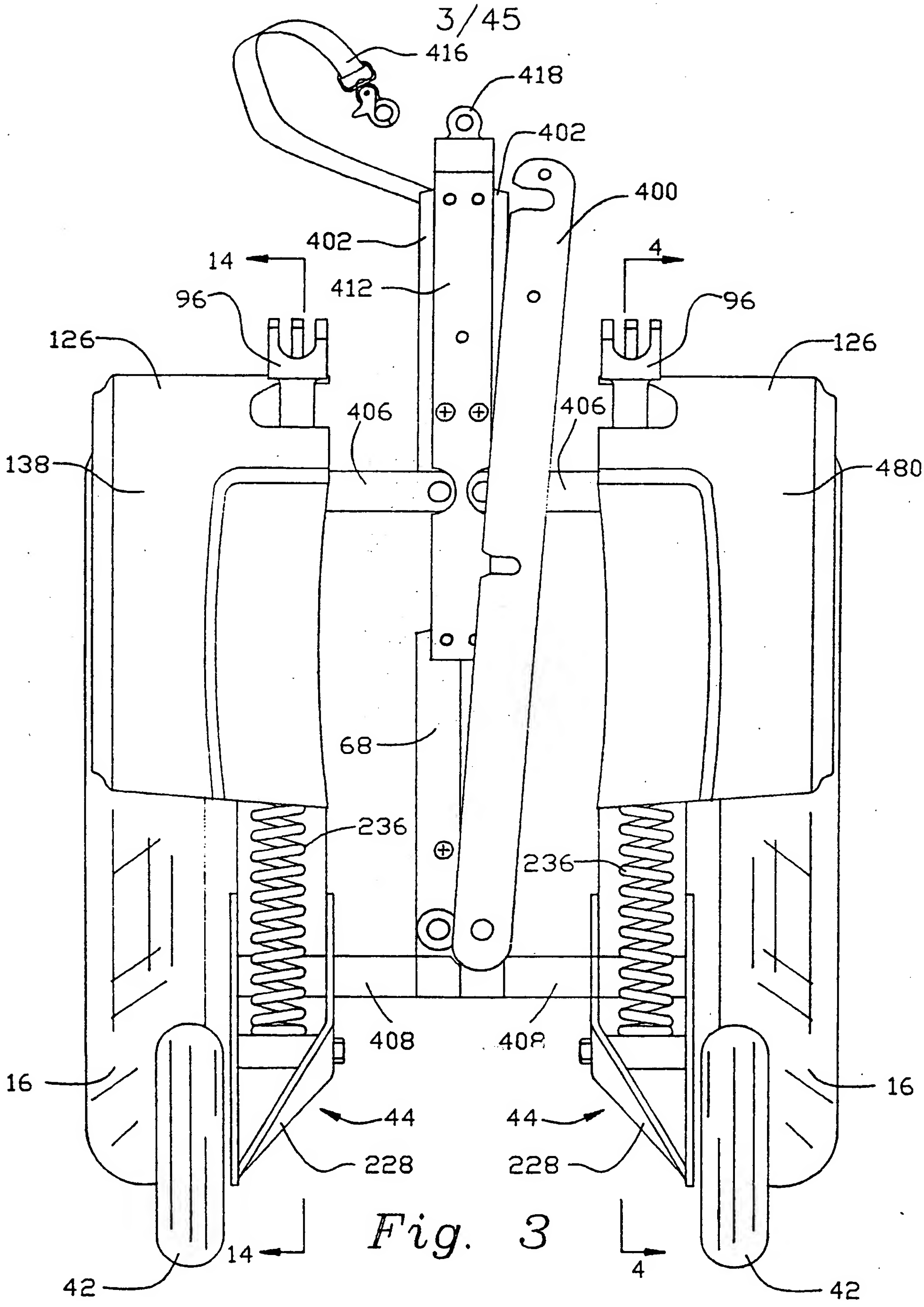
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Fig. 3

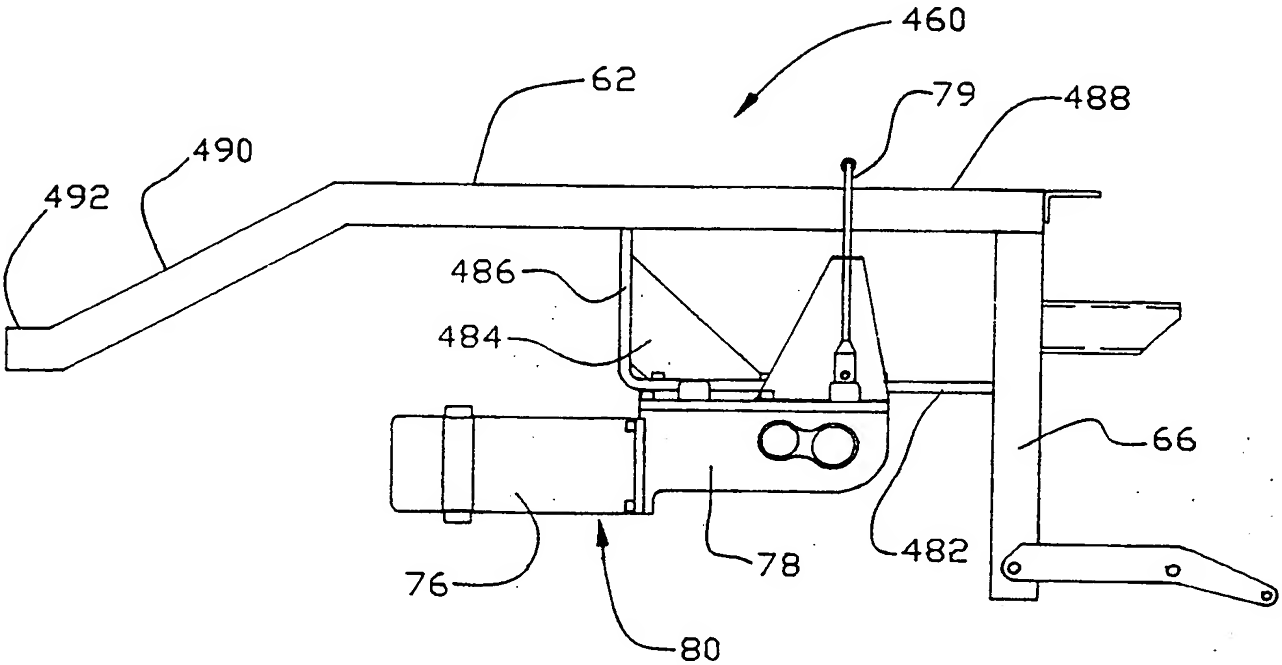

Fig. 4

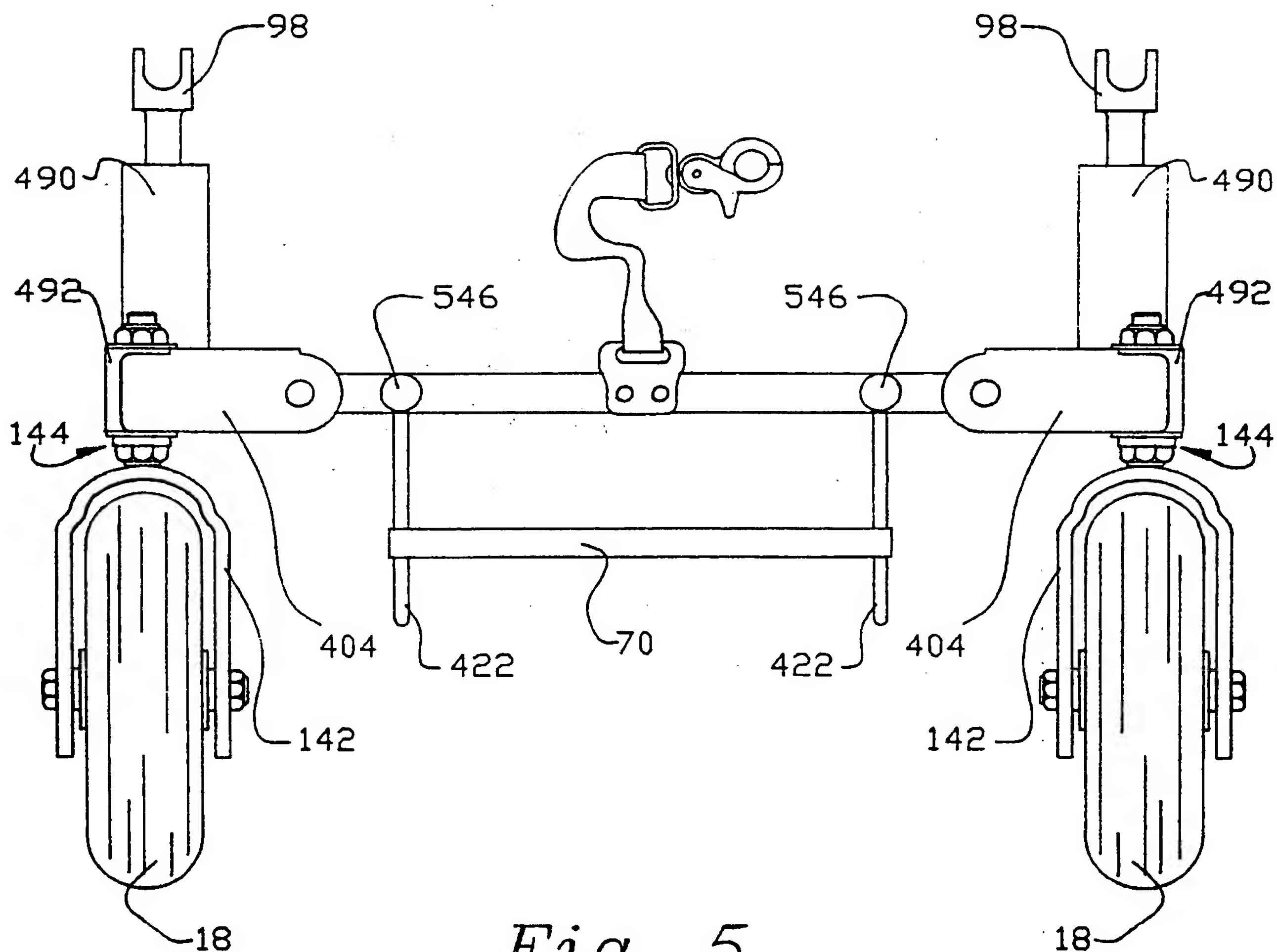
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Fig. 5

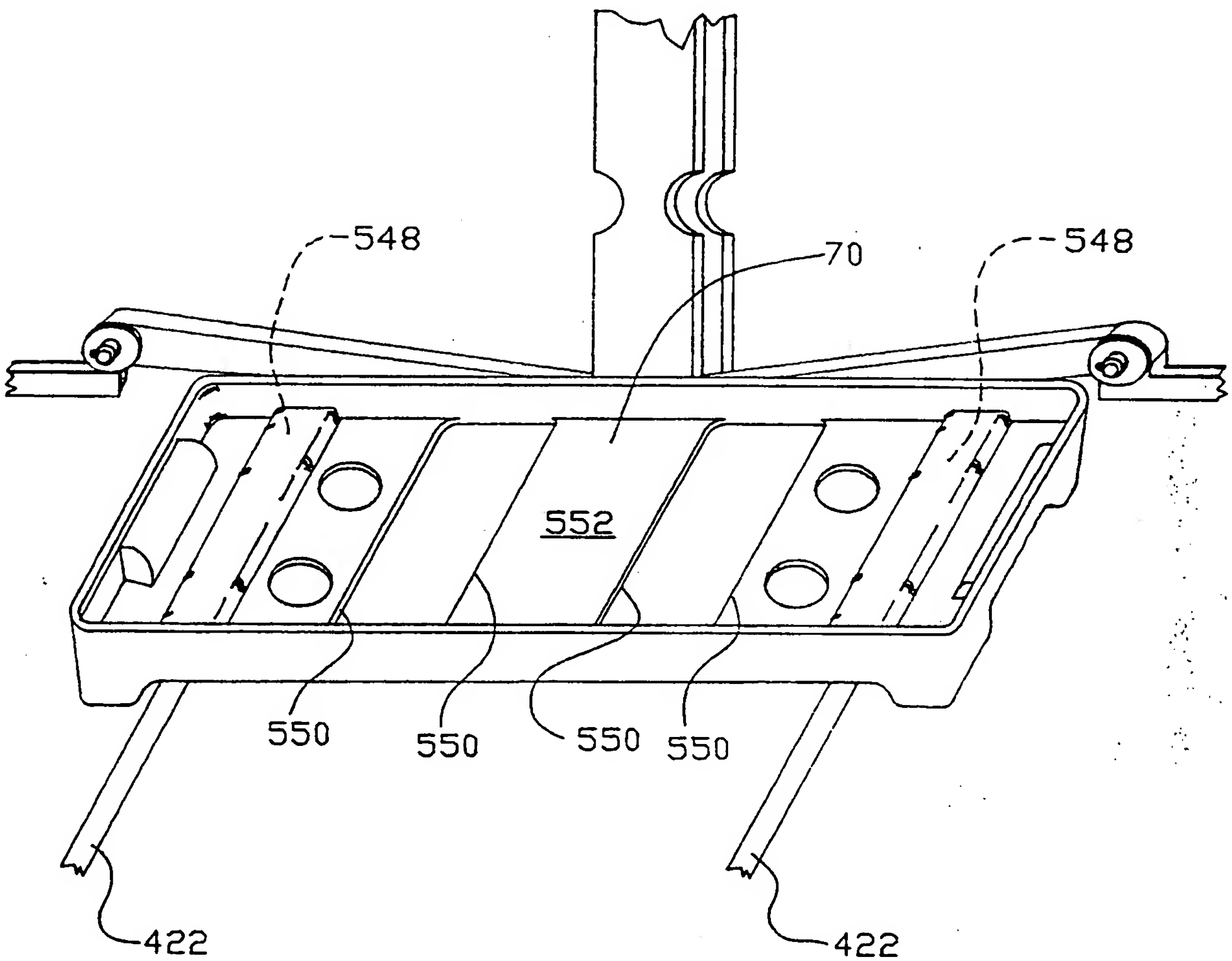


Fig. 6

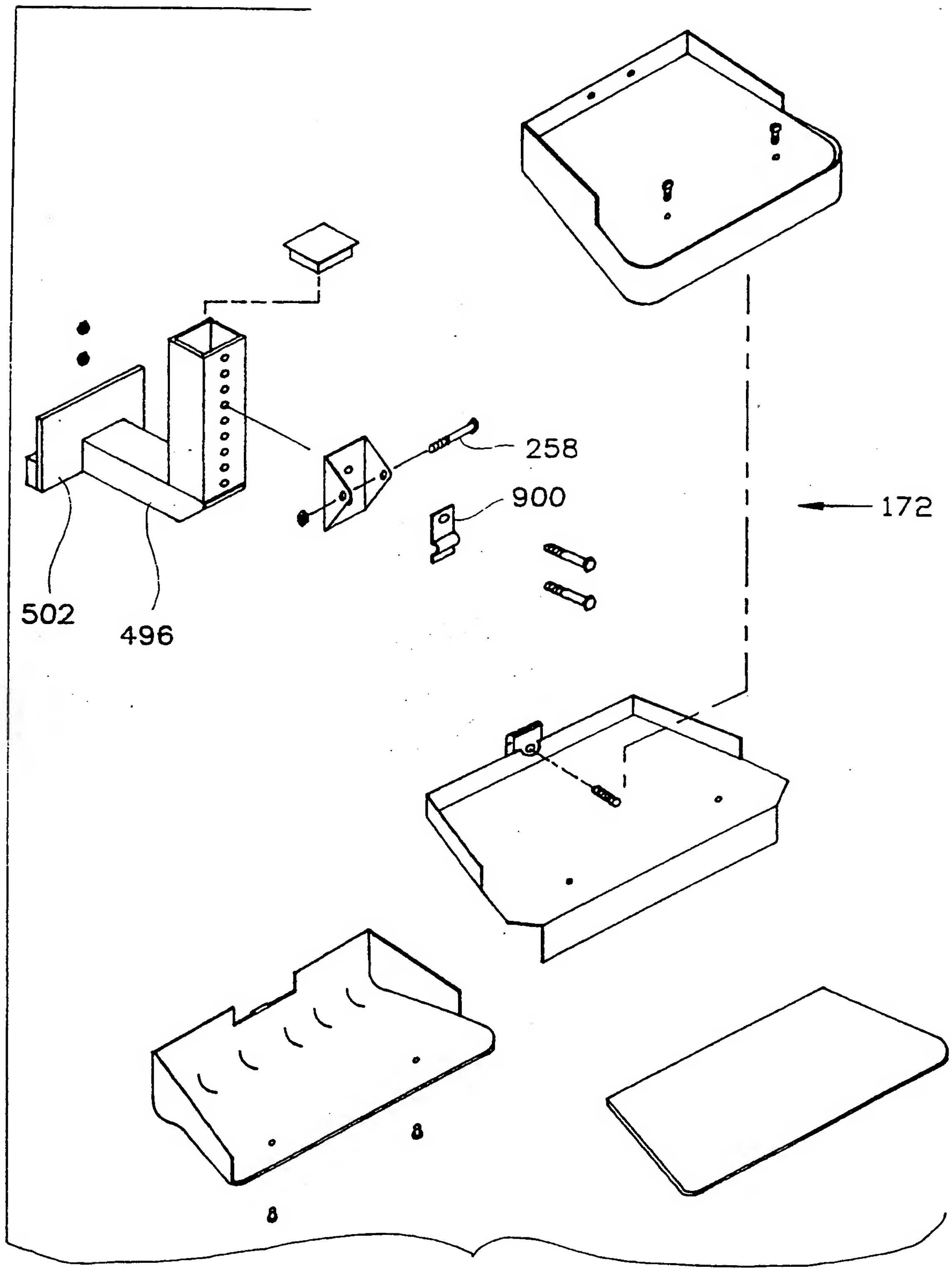


Fig. 7

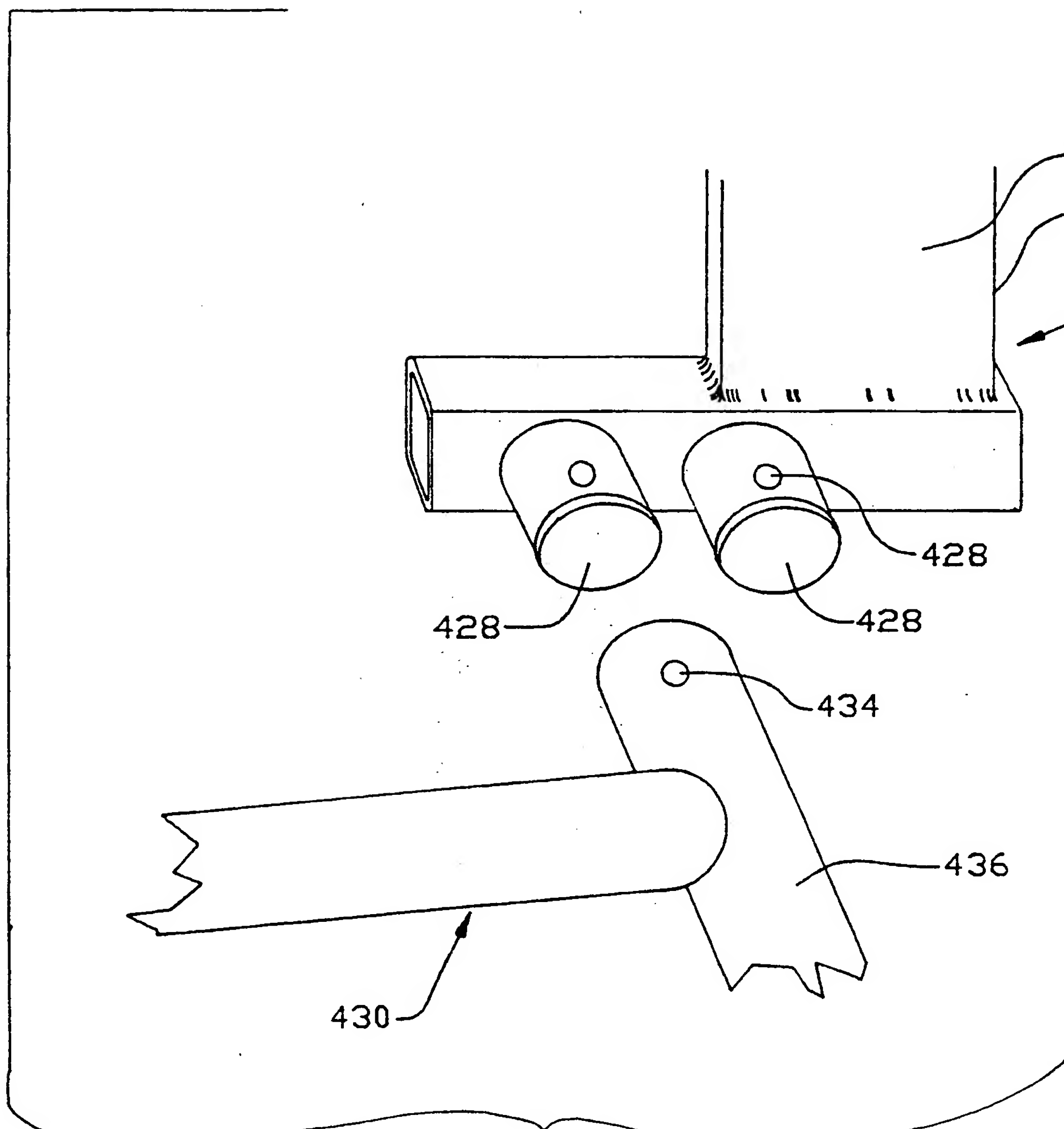


Fig. 8

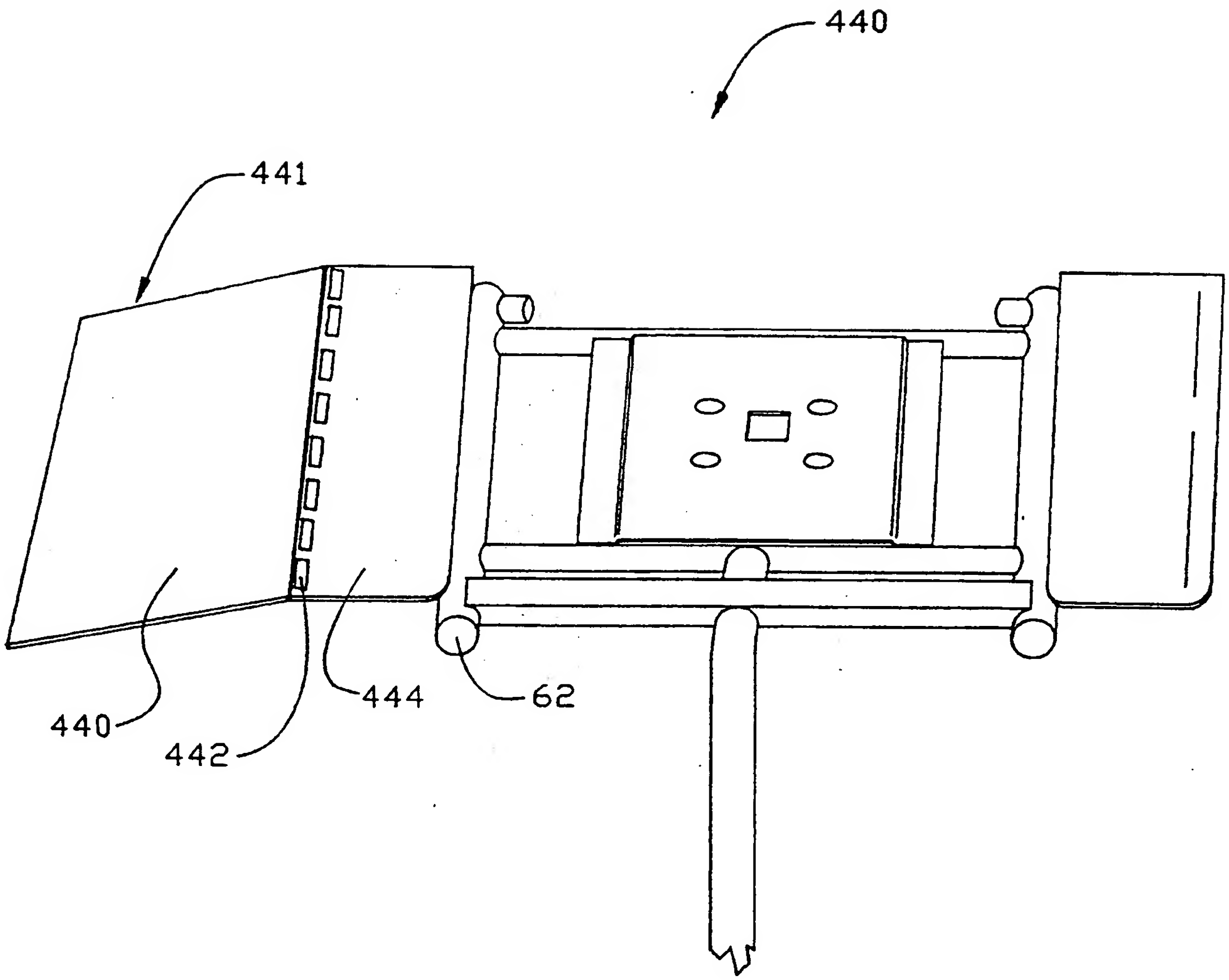


Fig. 9

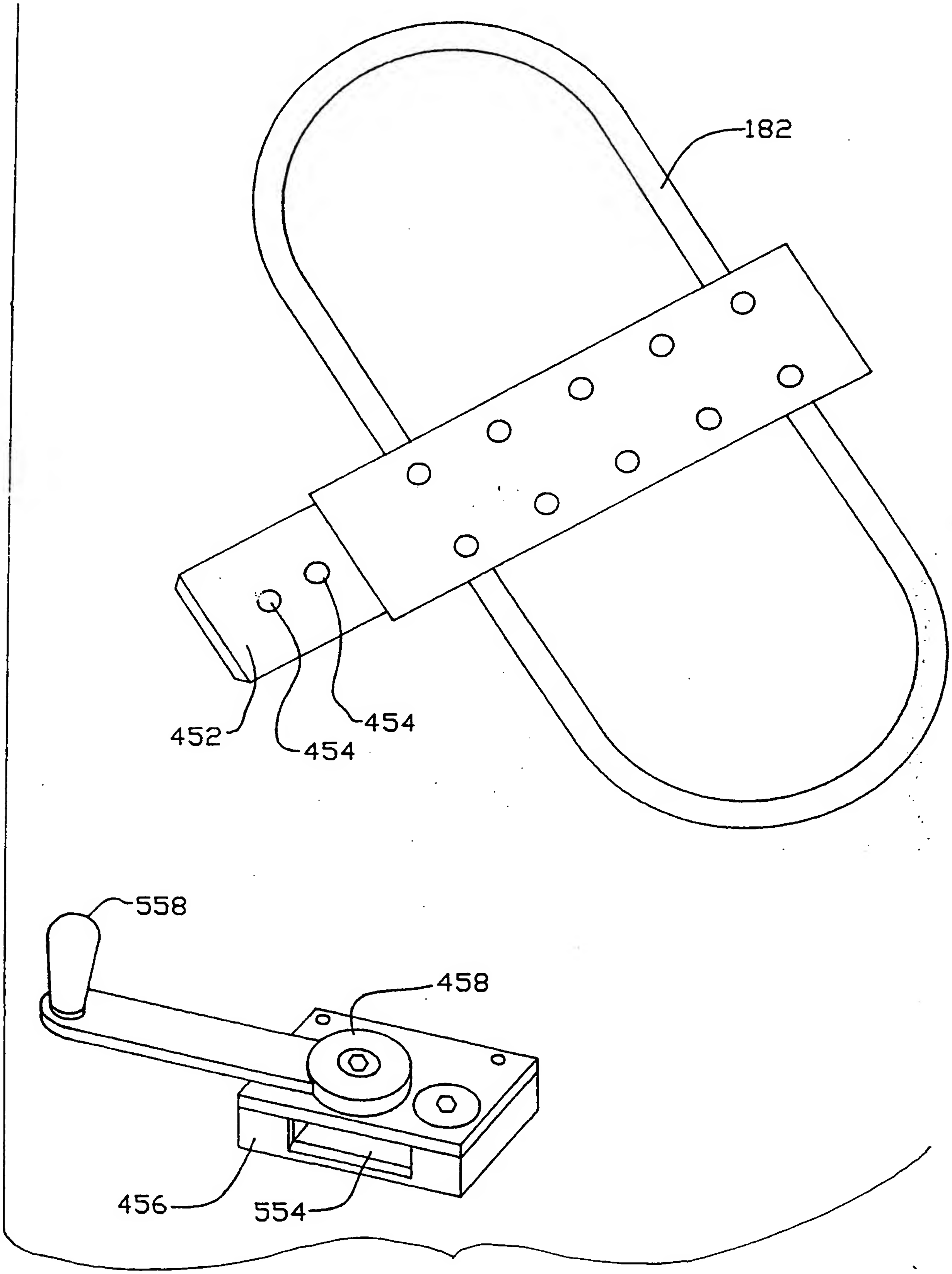


Fig. 10

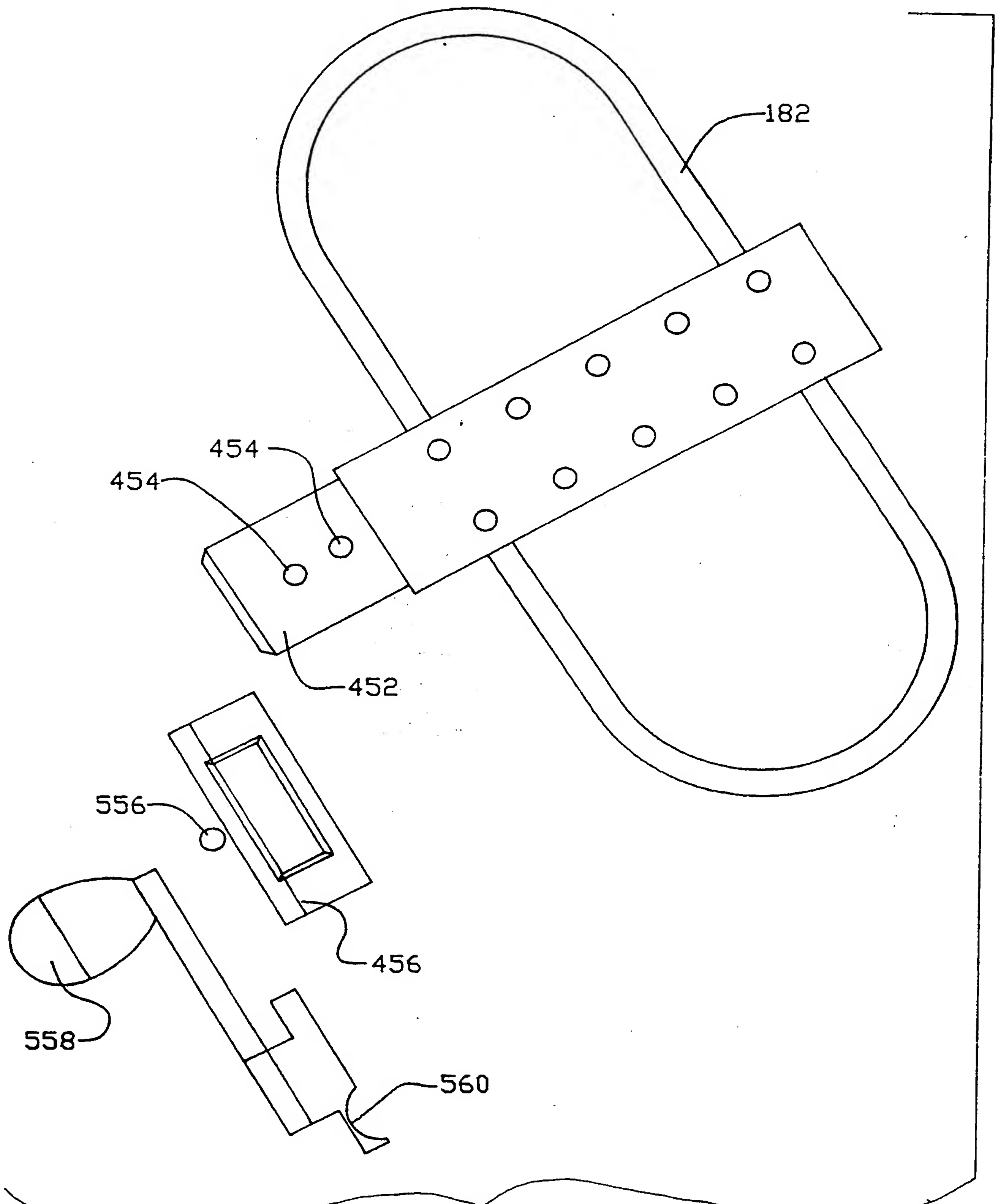


Fig. 11

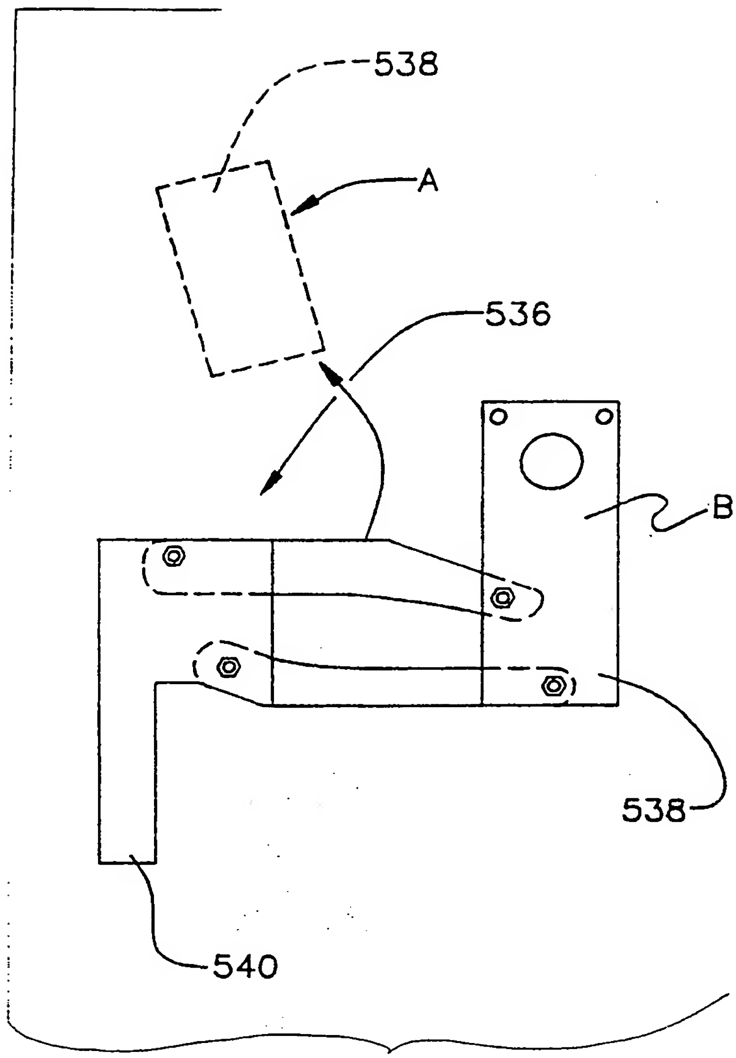


Fig. 12

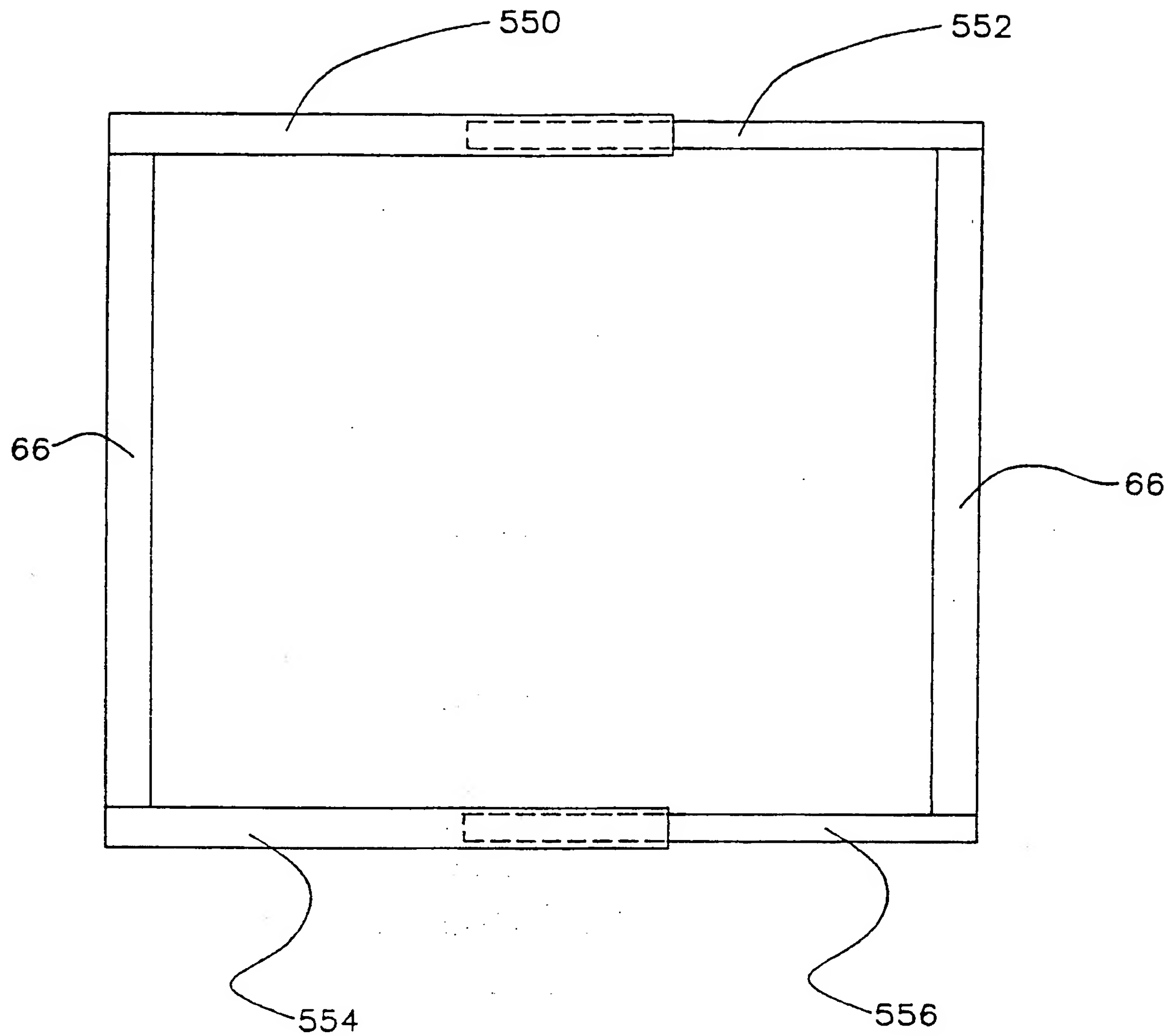
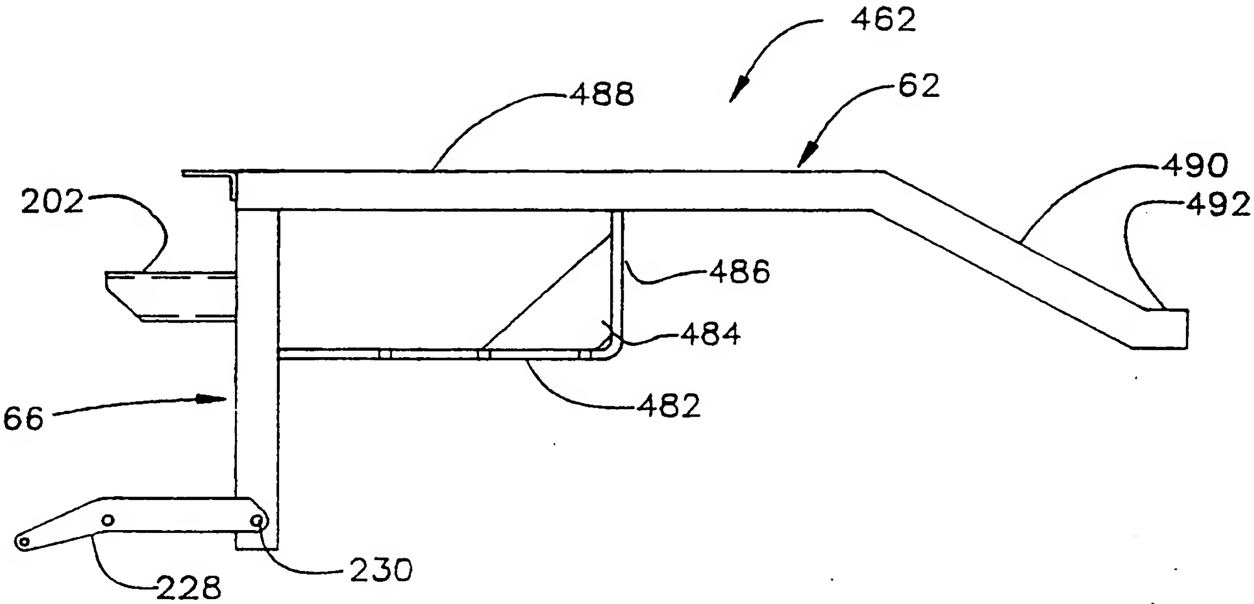


Fig. 13



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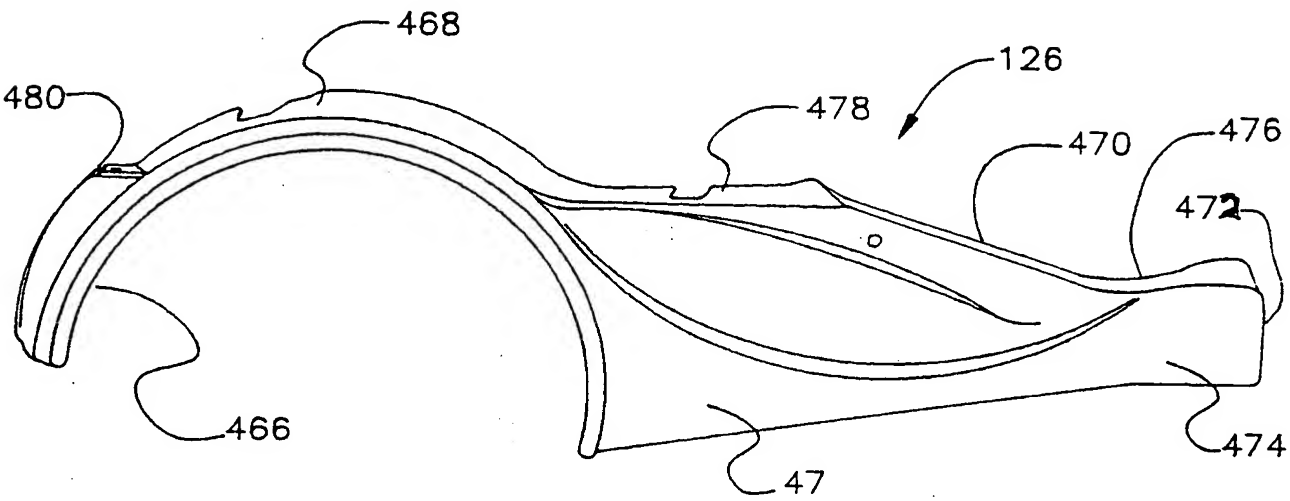


Fig. 15

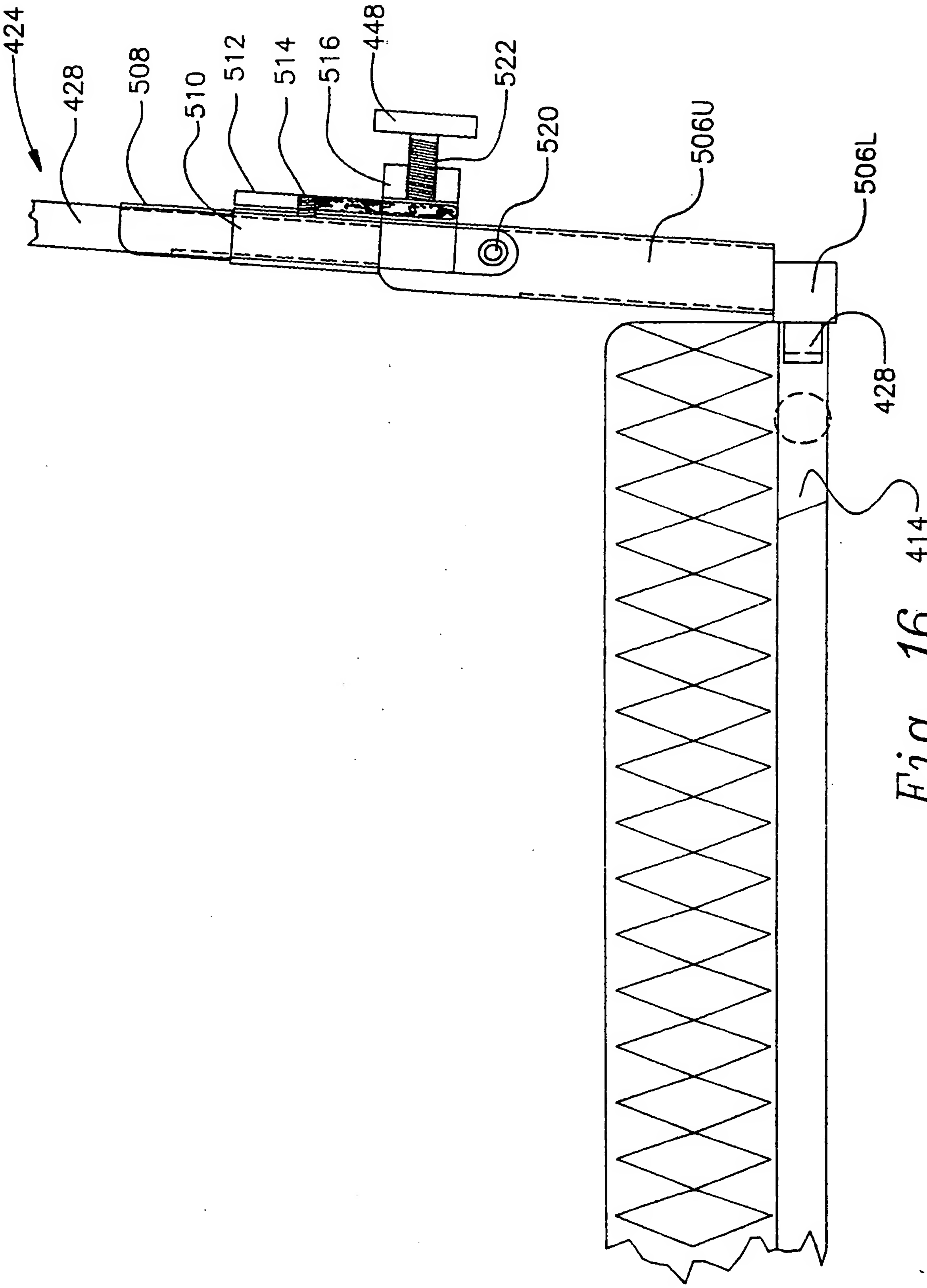


Fig. 16

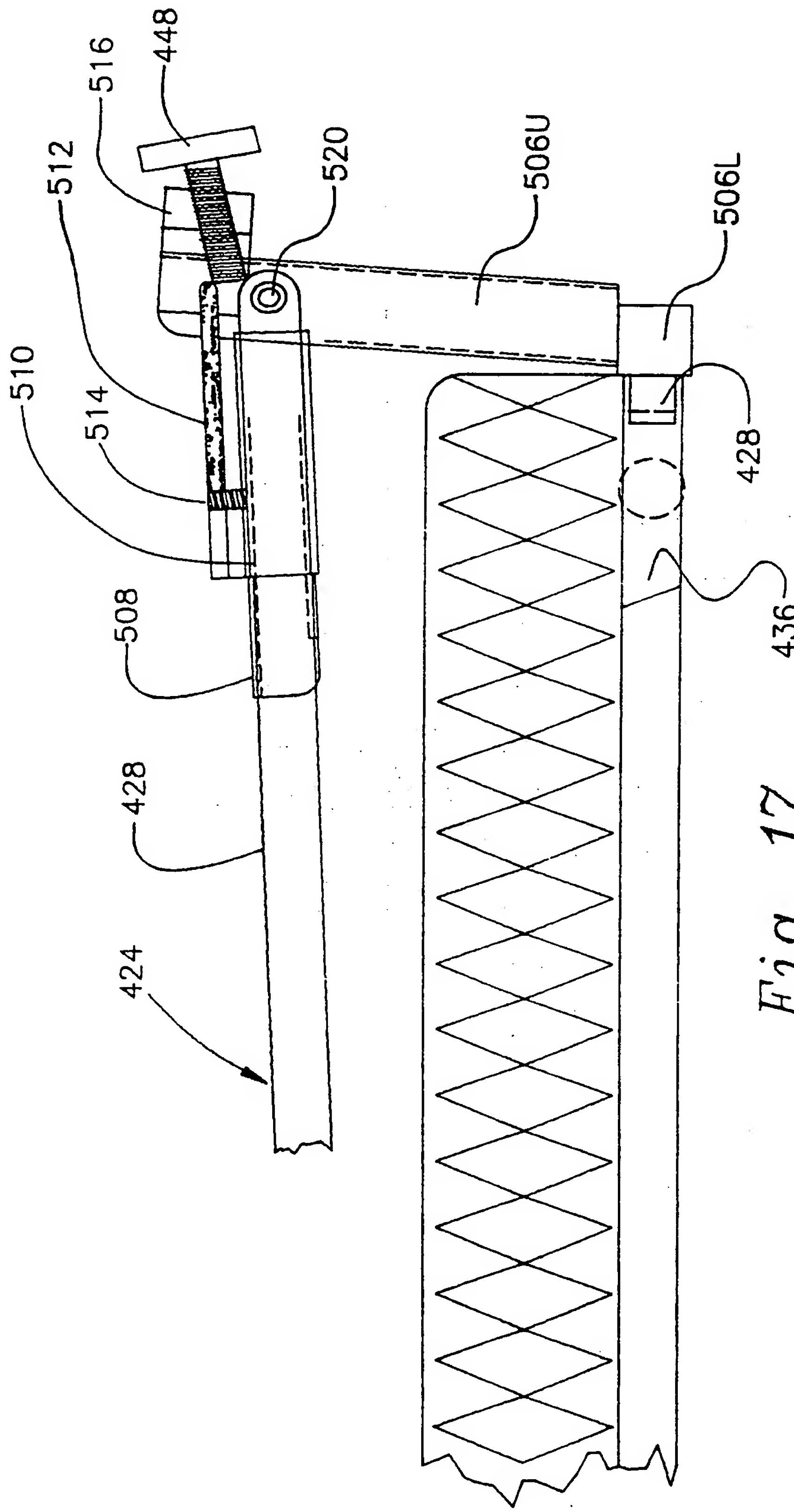


Fig. 17

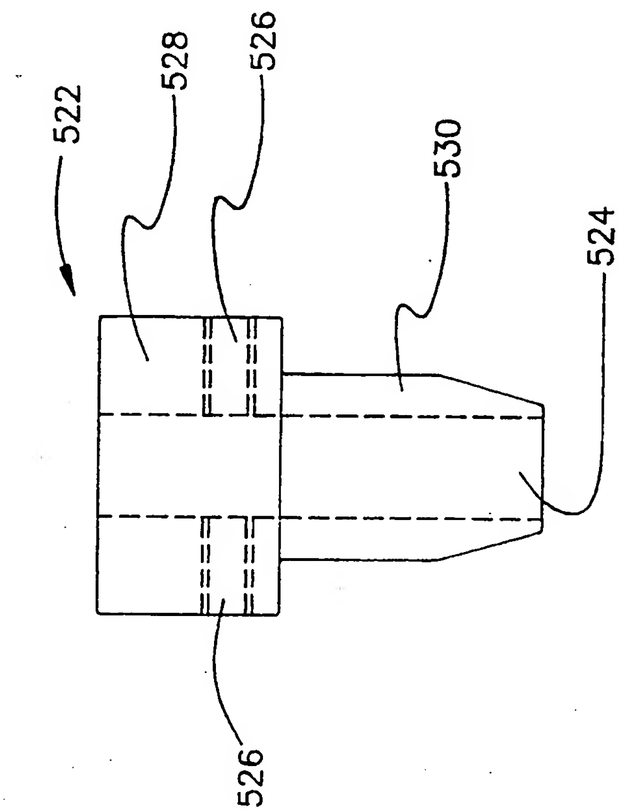
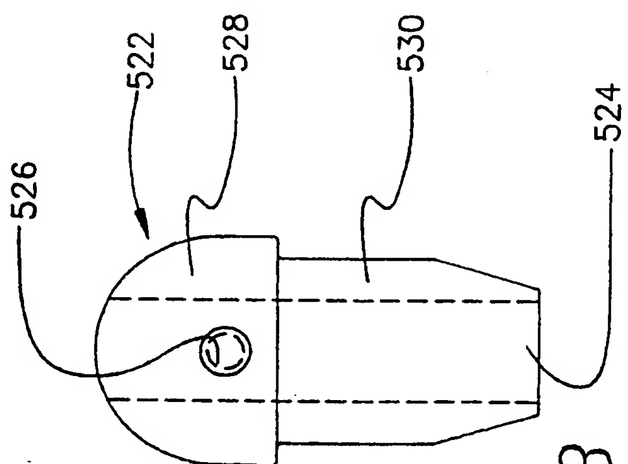


Fig. 20



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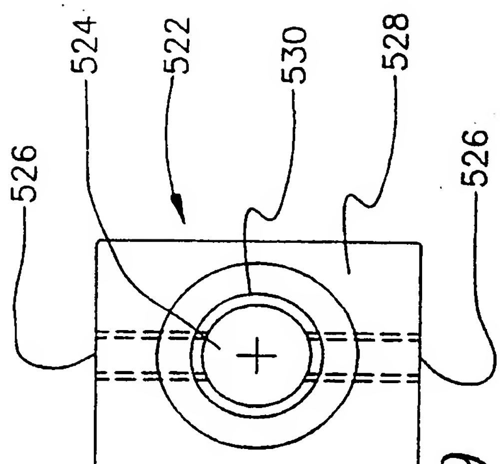

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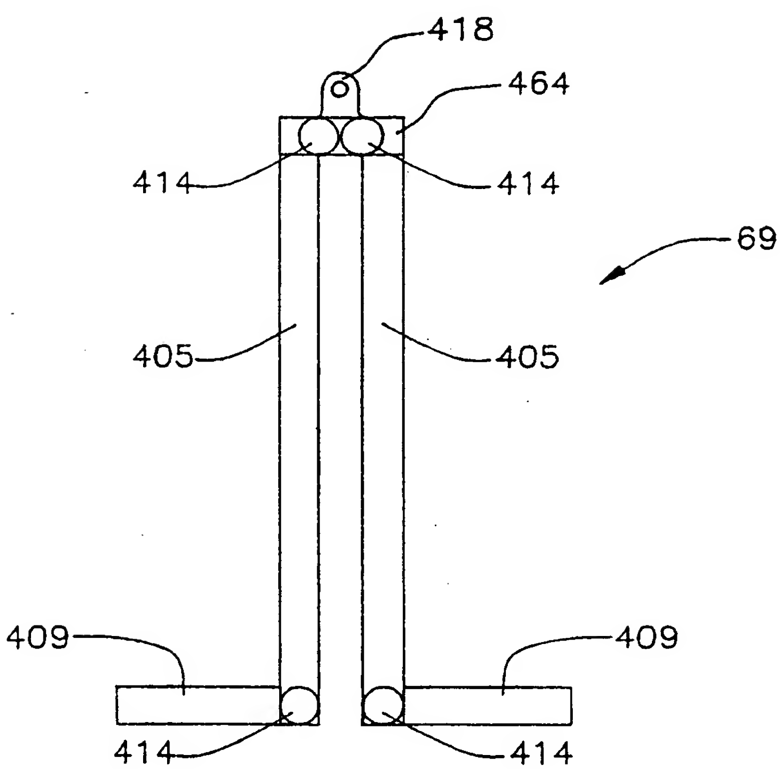

Fig. 21

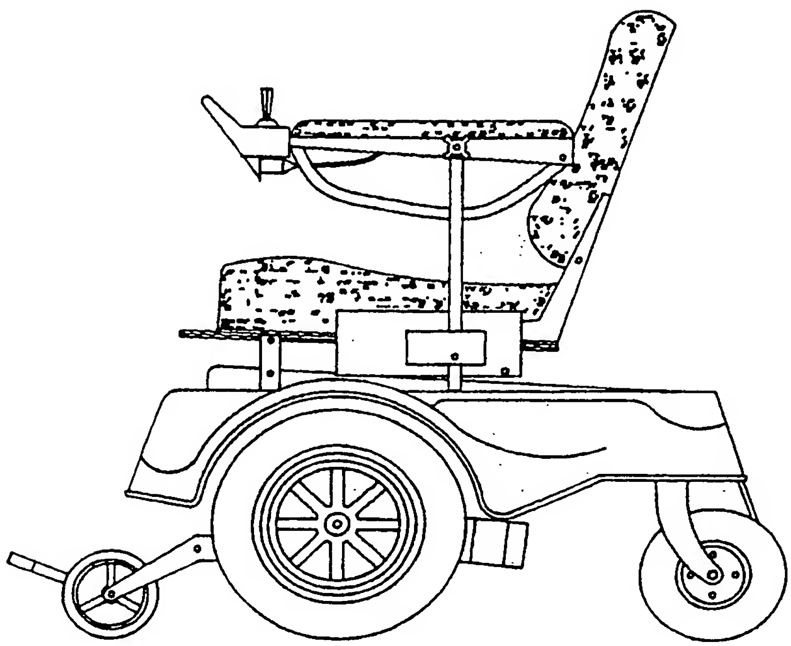

Fig. 22

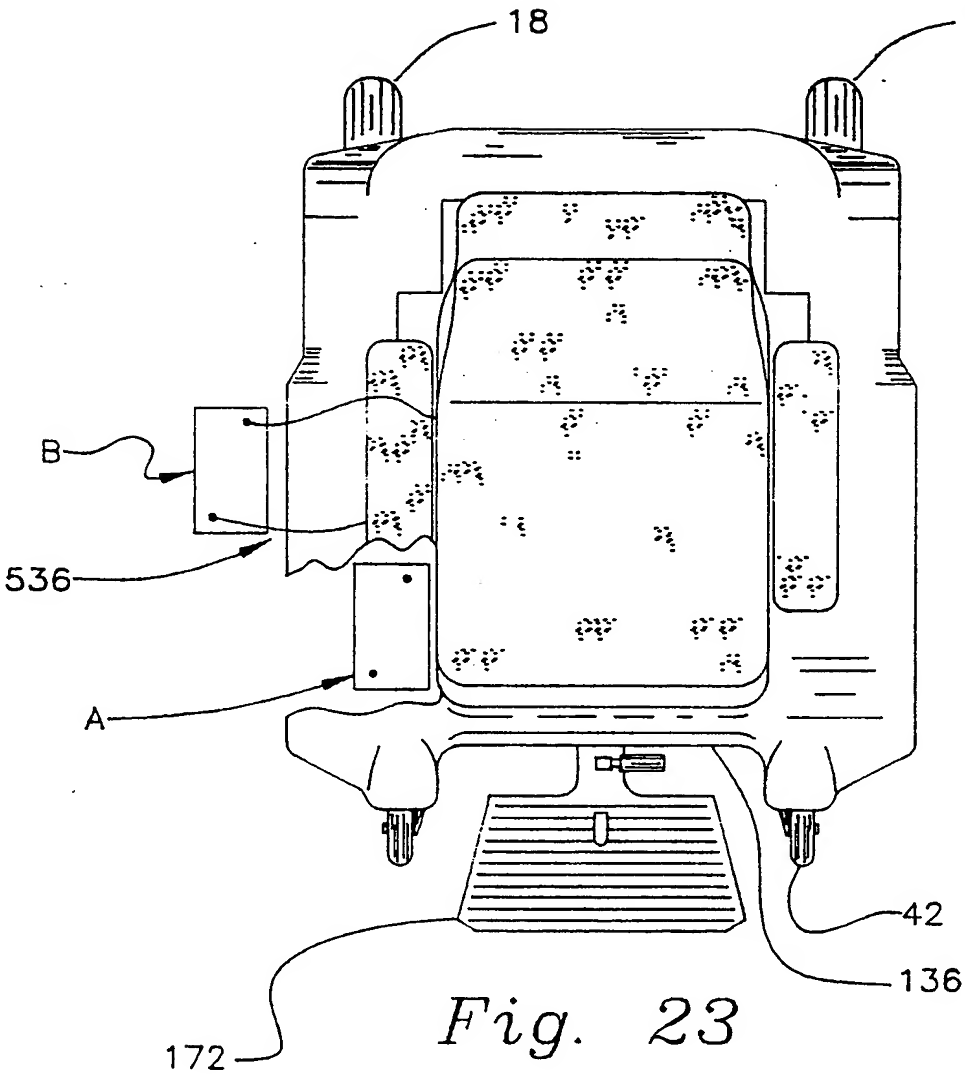

Fig. 23

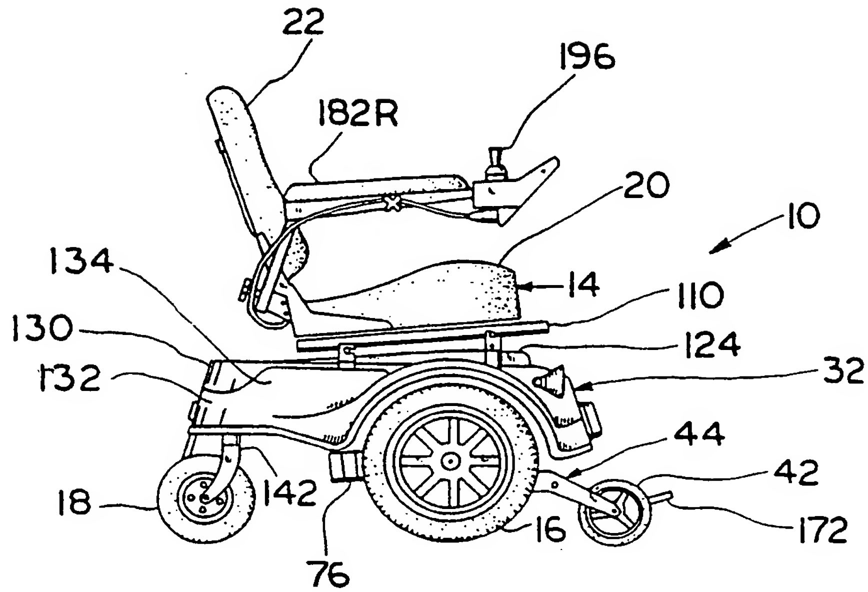

FIG. A

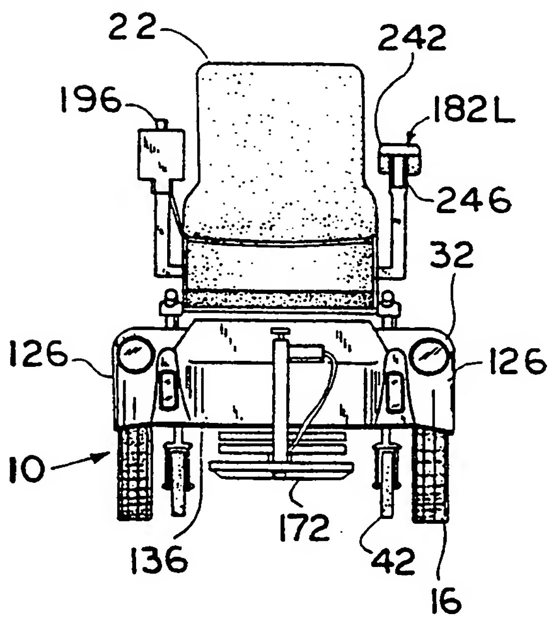

FIG. B

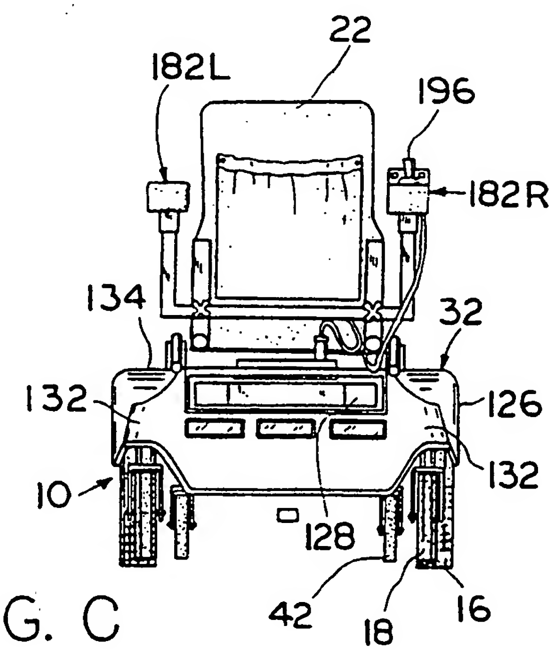

FIG. C

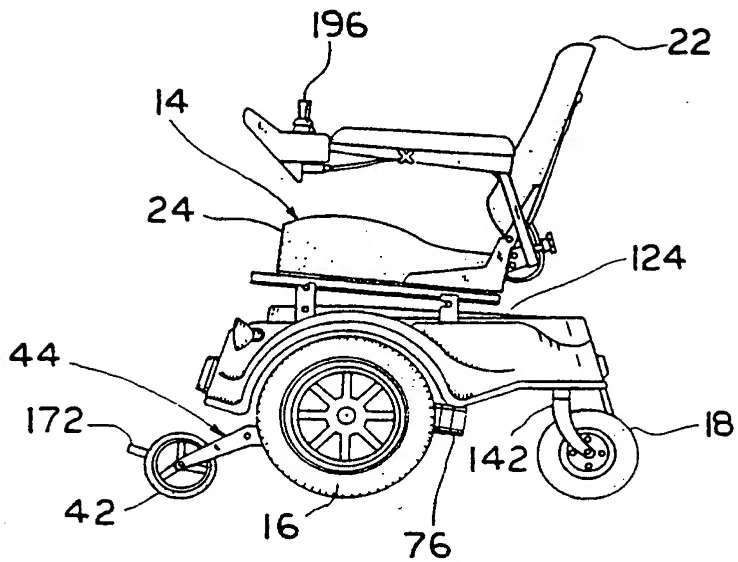

FIG. D

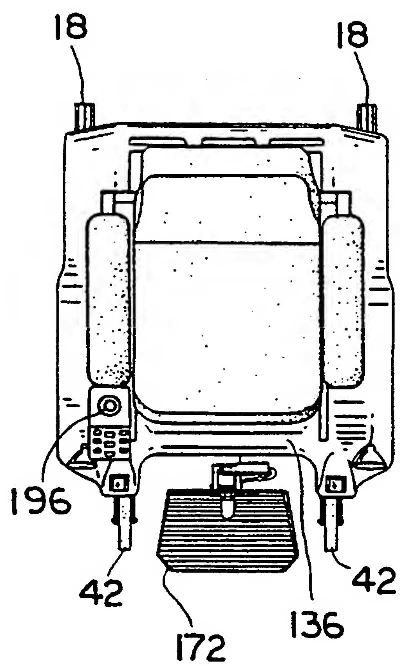

FIG. E

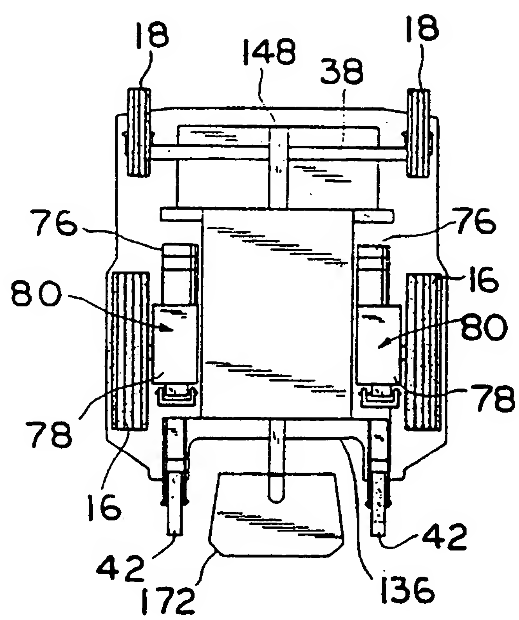

FIG. F

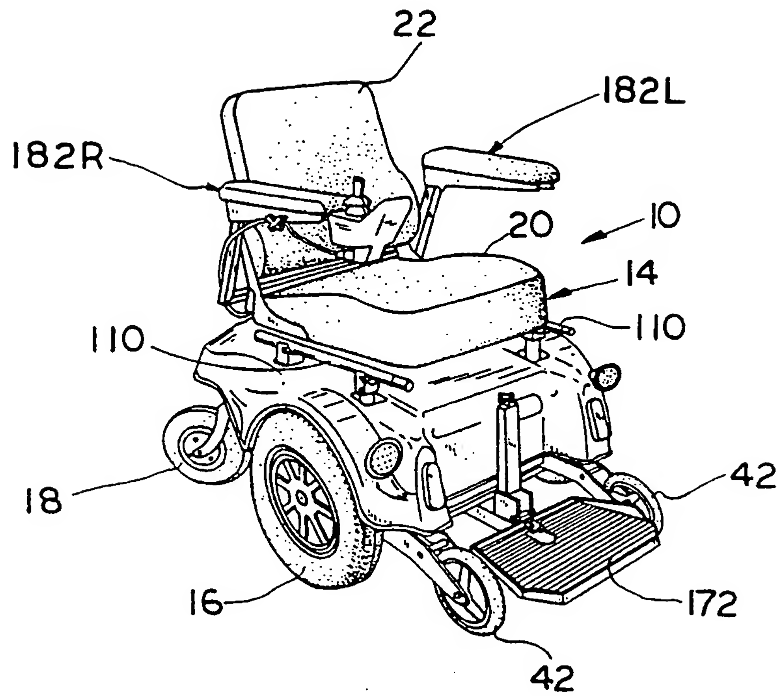
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FIG. G

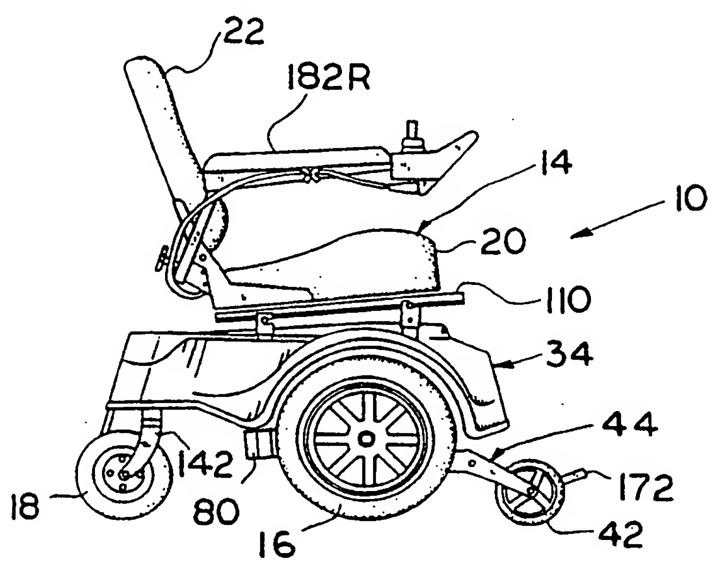
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FIG. H

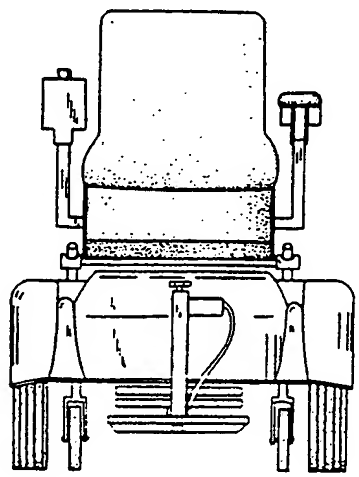

FIG. I

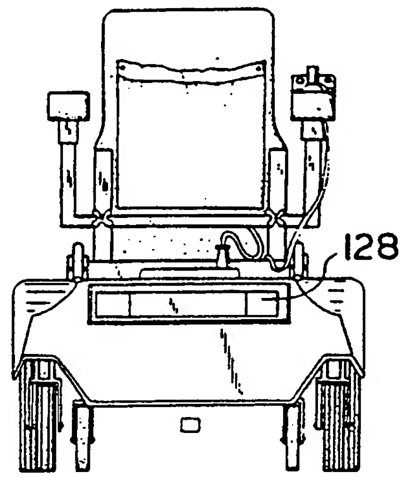

FIG. J

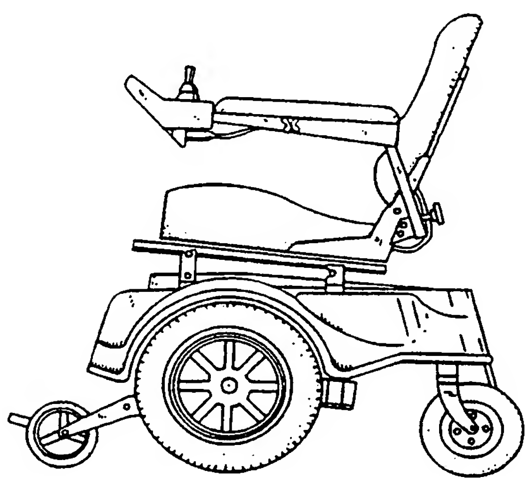

FIG. K

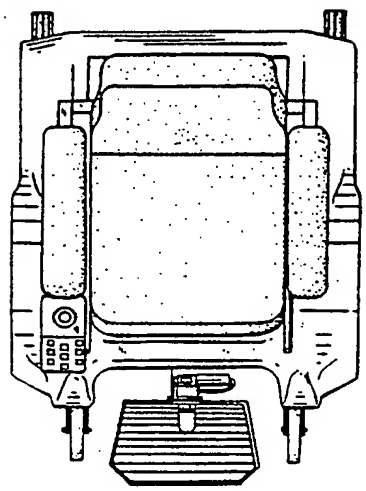

FIG. L

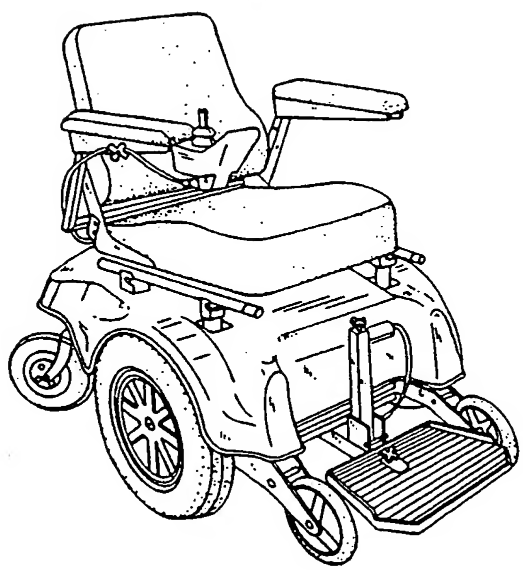

FIG. M

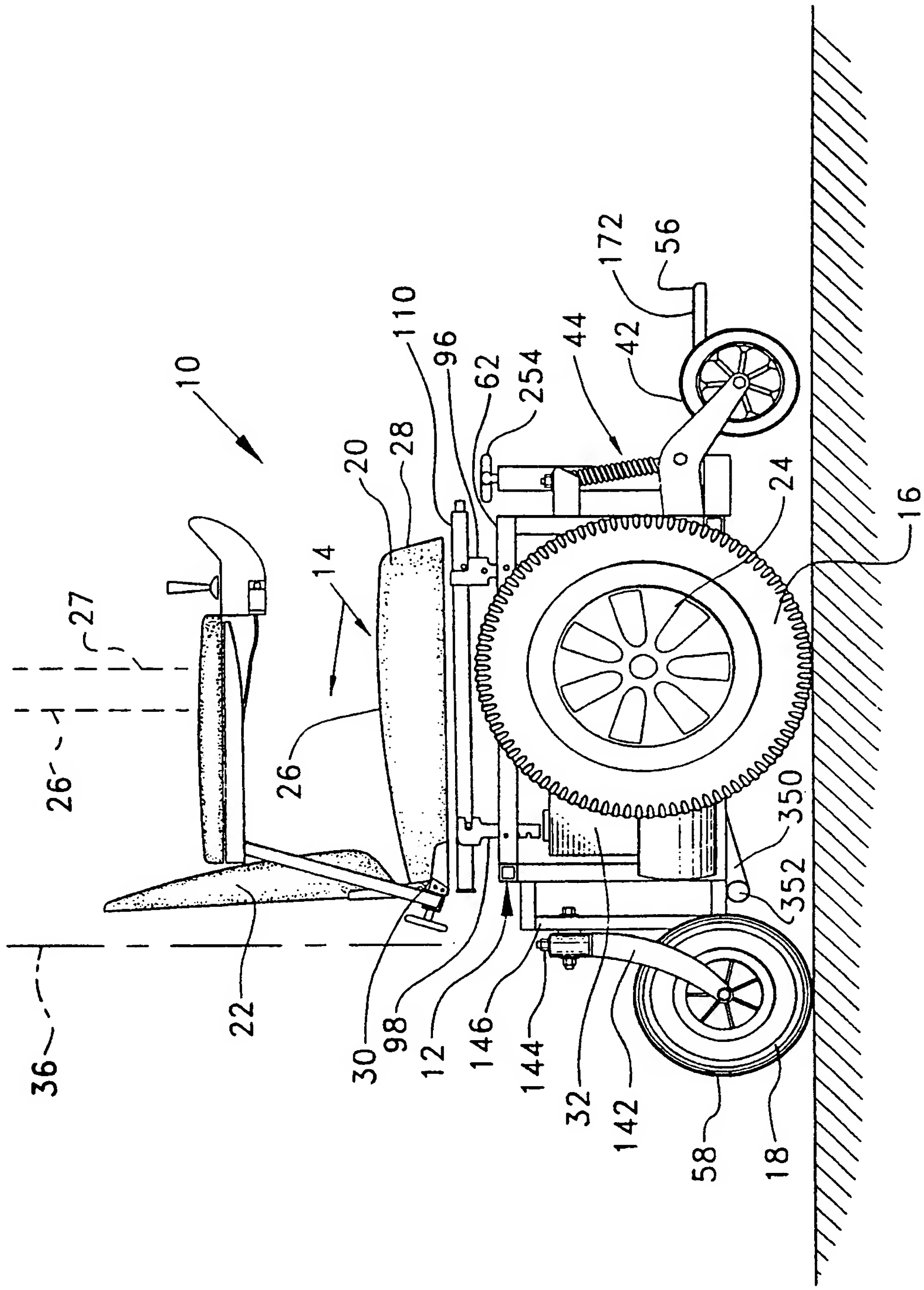
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FIG. N

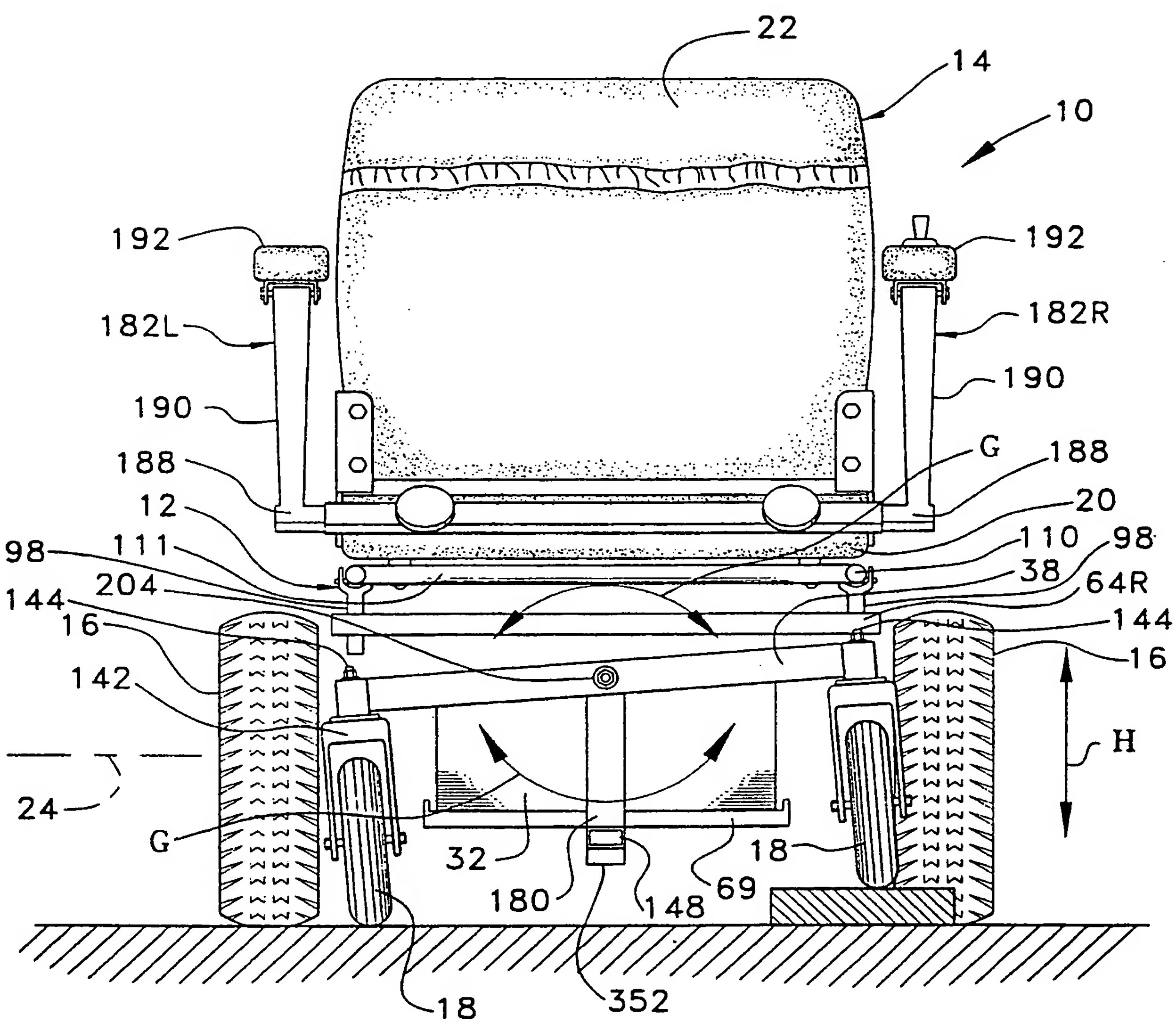
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FIG. O

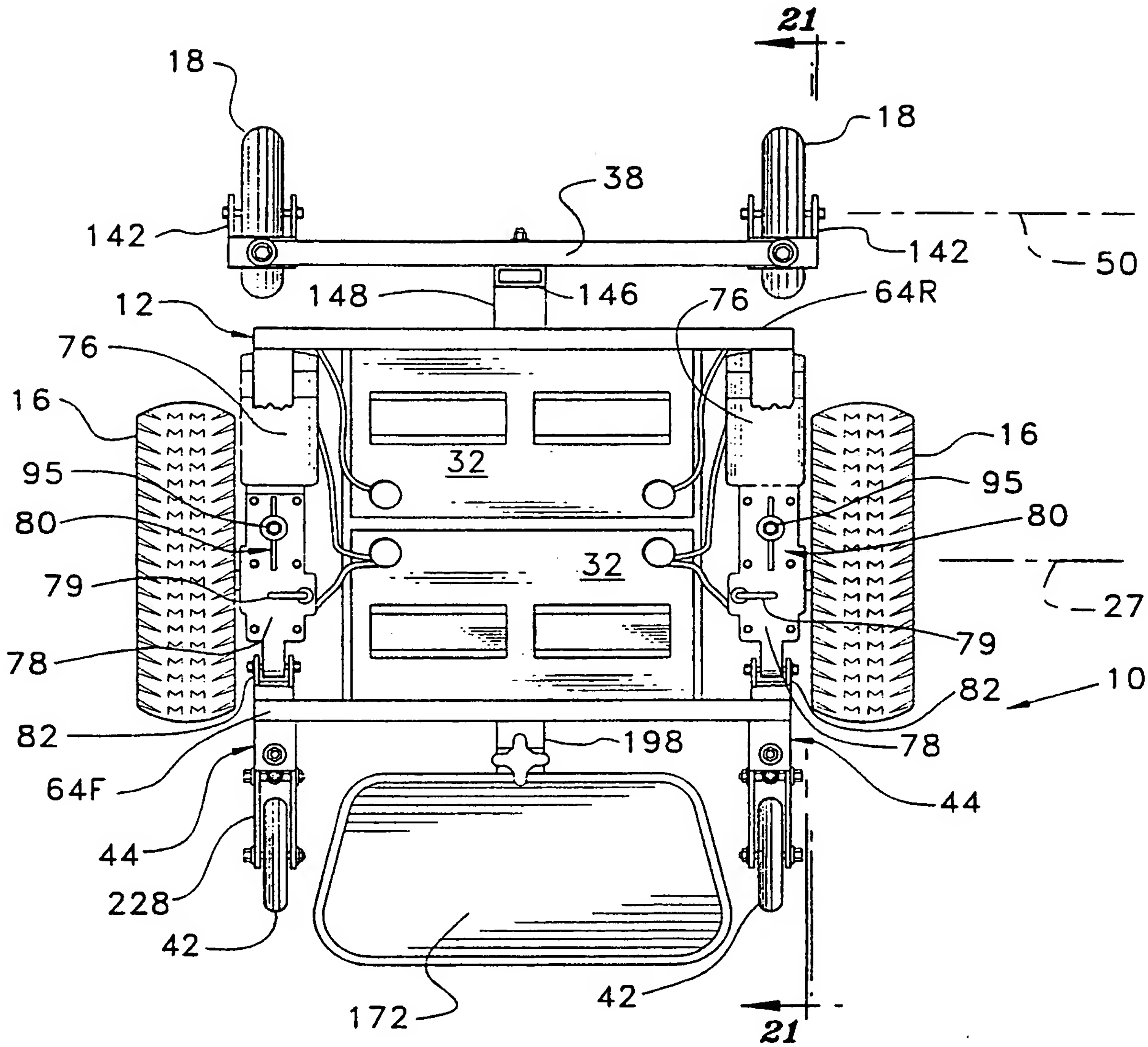
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FIG. P

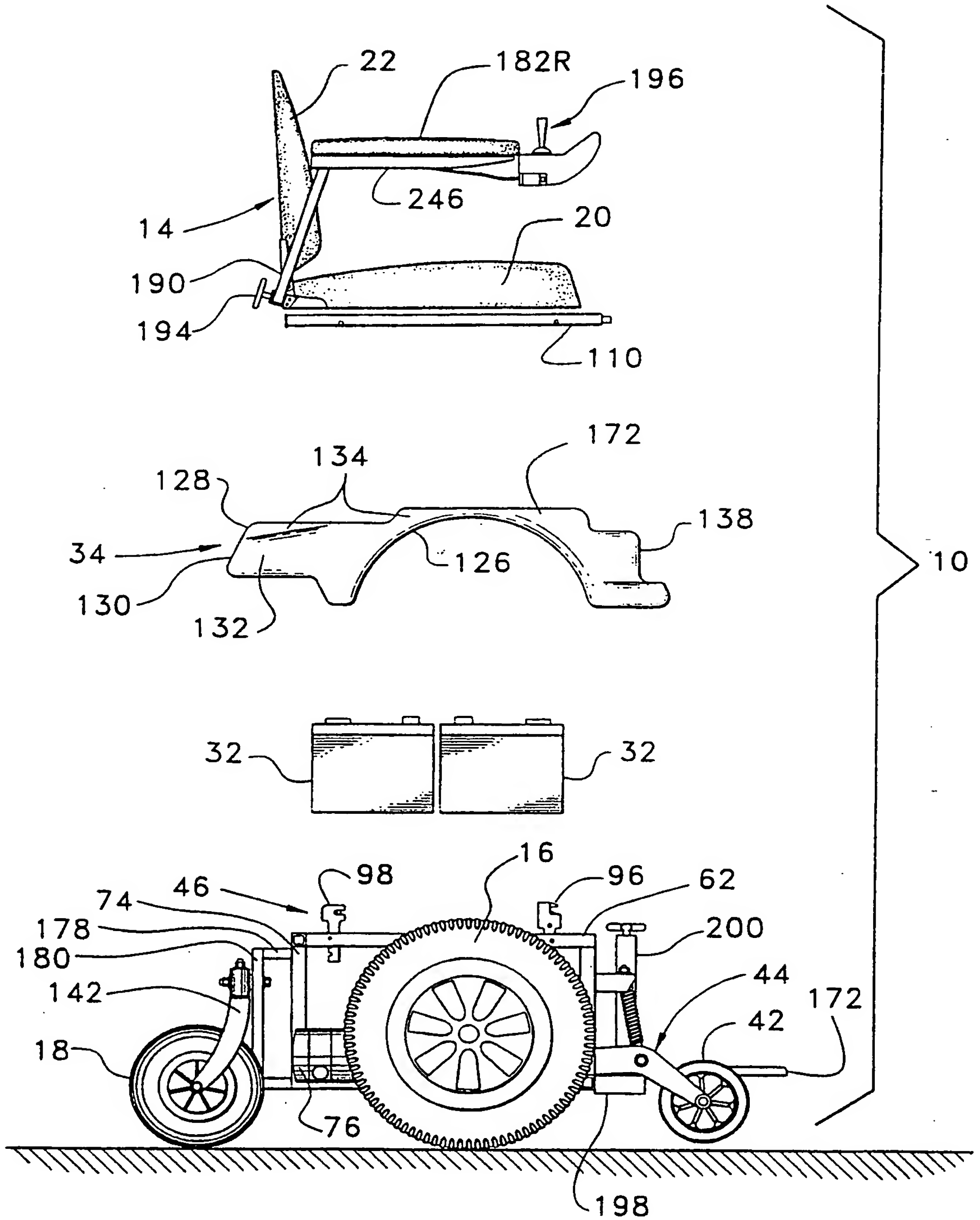
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FIG. Q

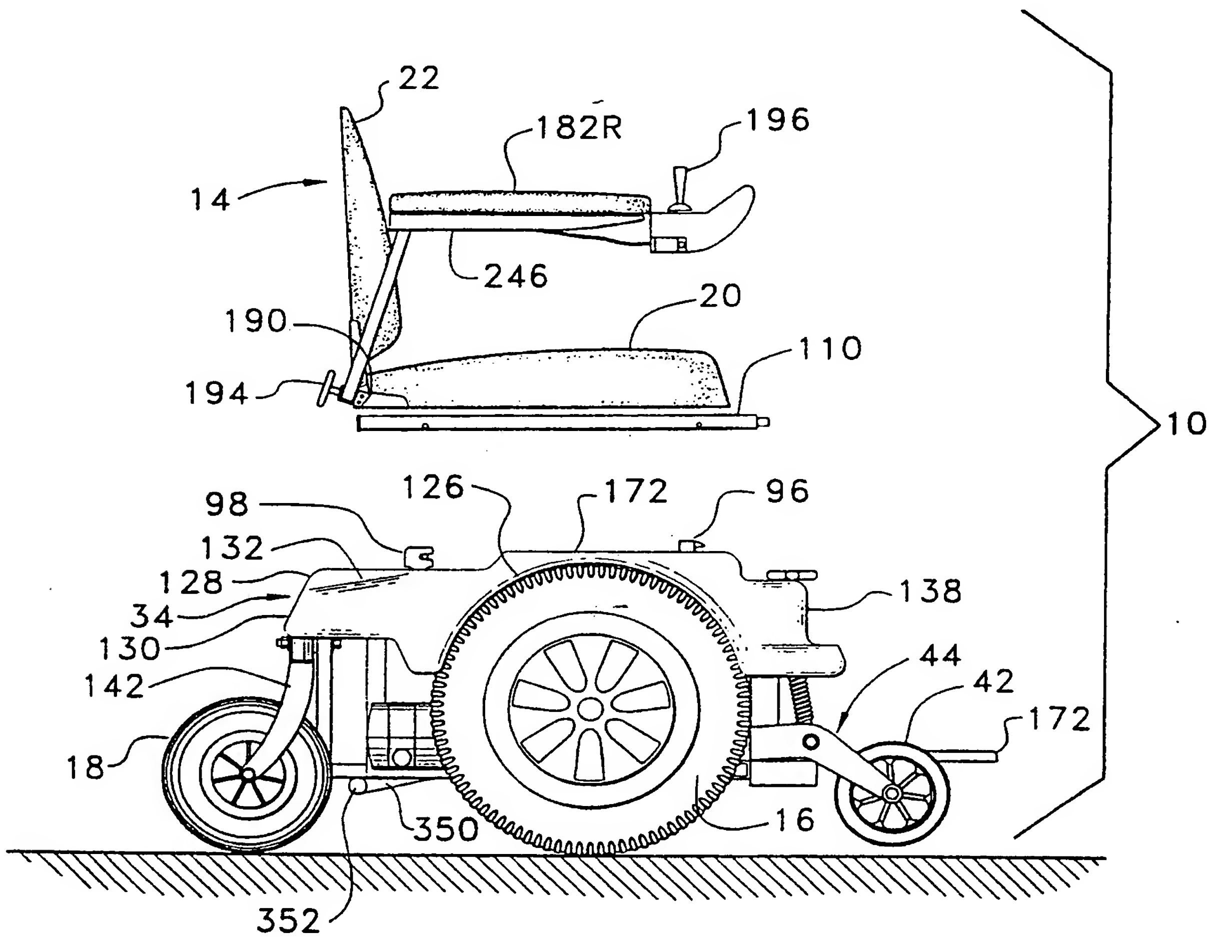
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FIG. R

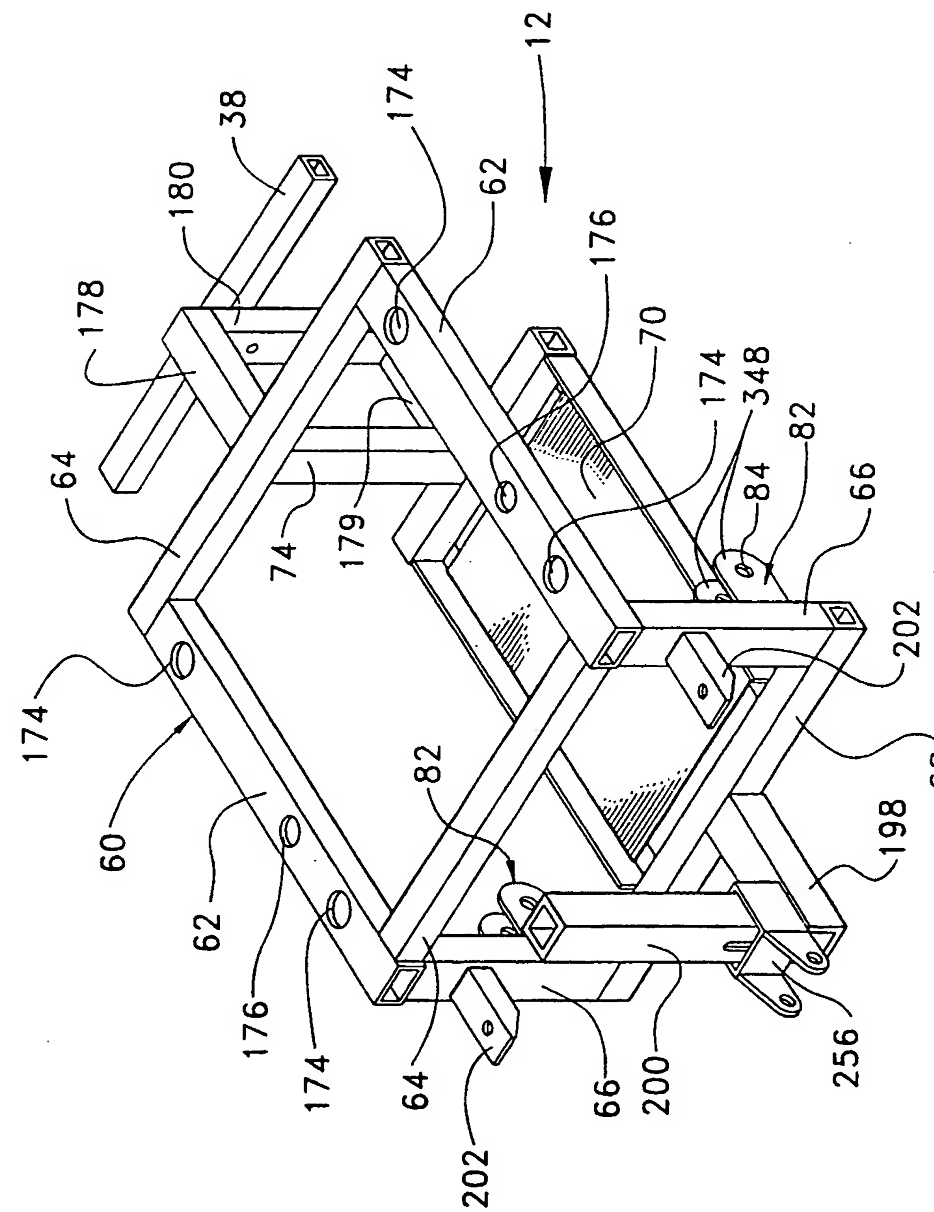
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FIG. S

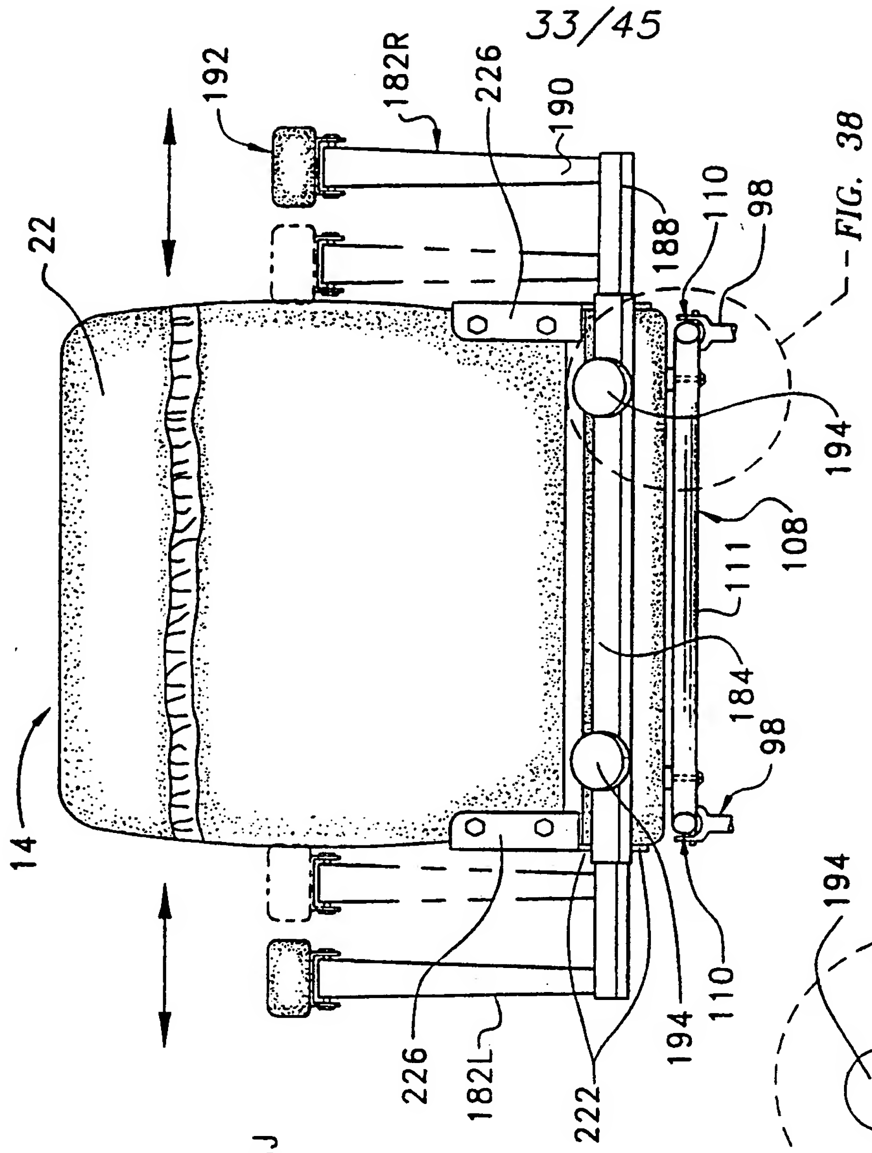

FIG. T

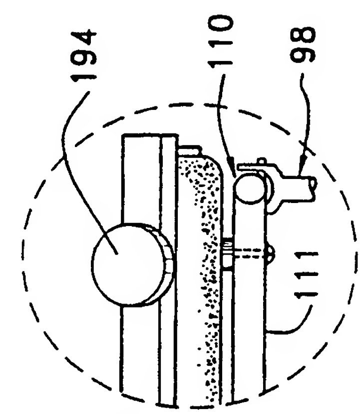

FIG. LL

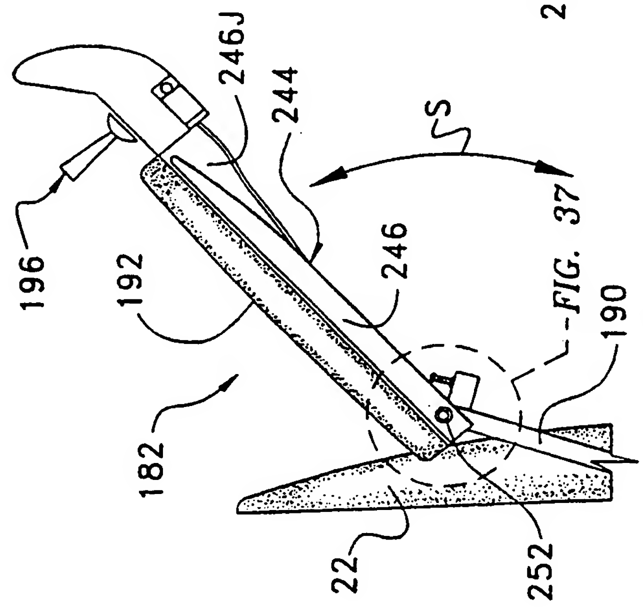

FIG. JJ

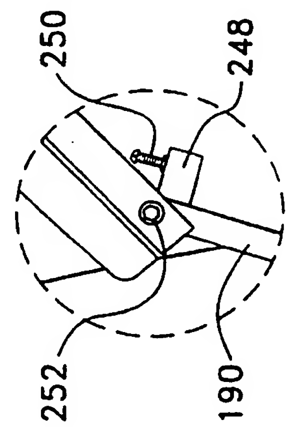

FIG. KK

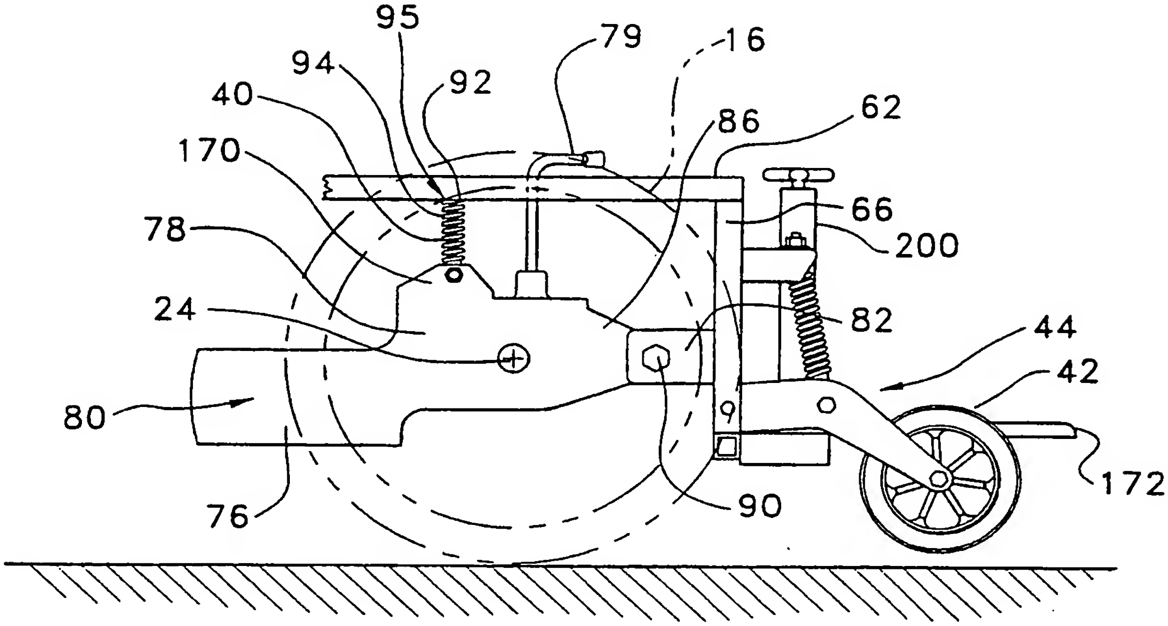
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FIG. U

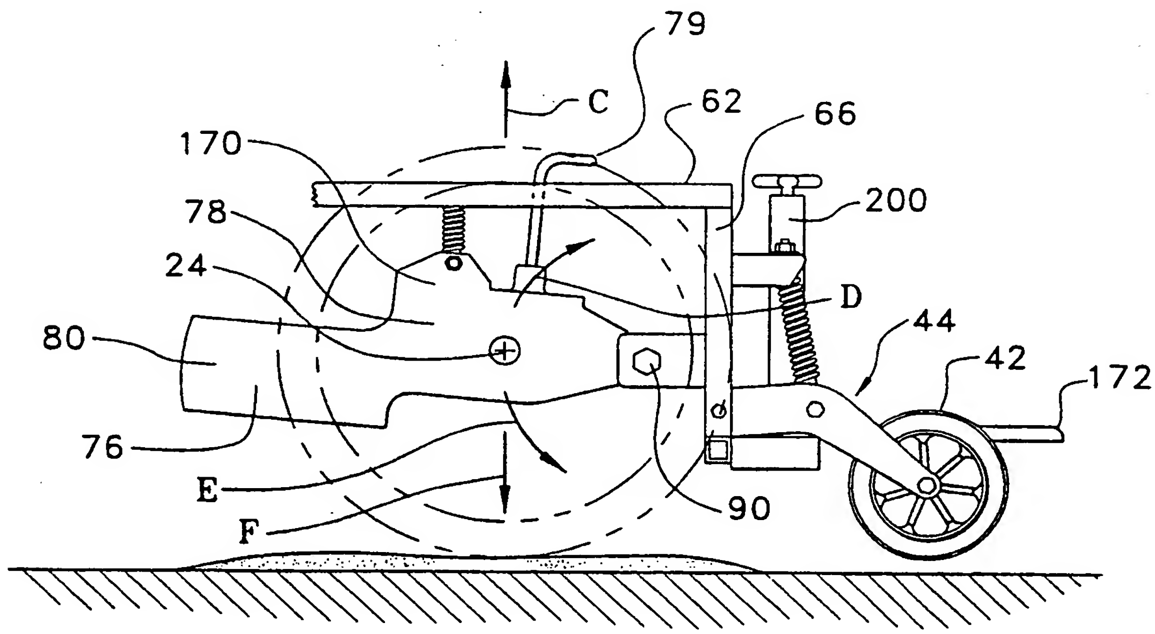
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FIG. V

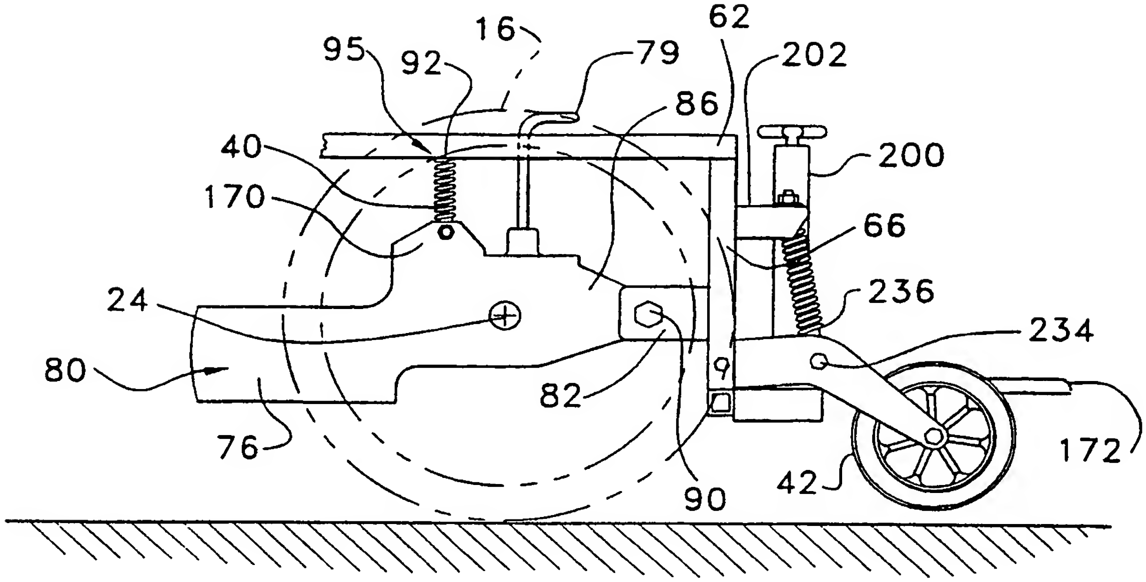

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FIG. W

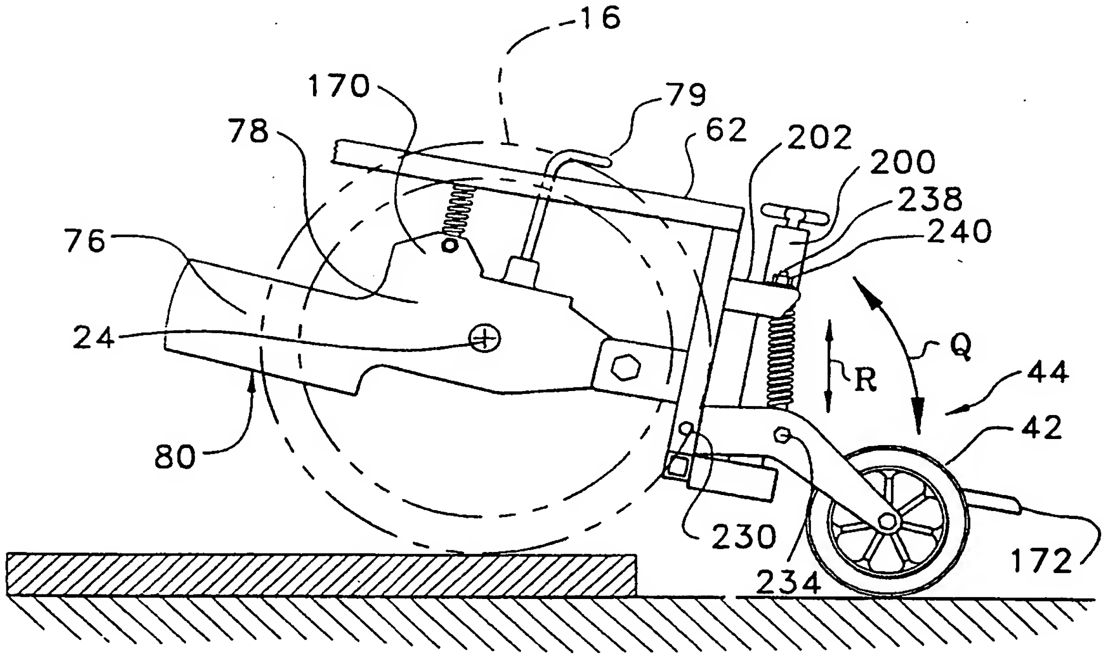

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FIG. X

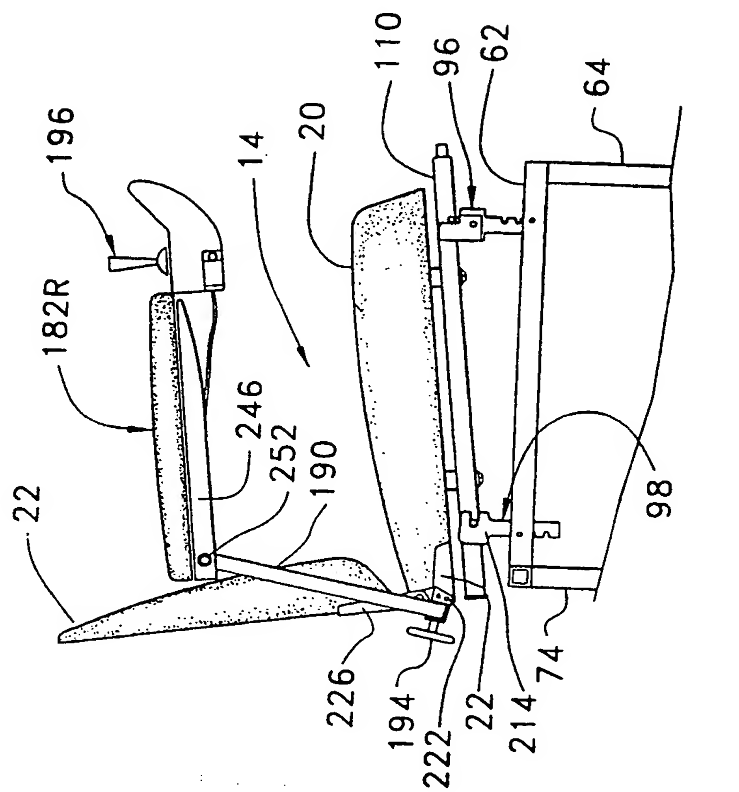
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FIG. AA

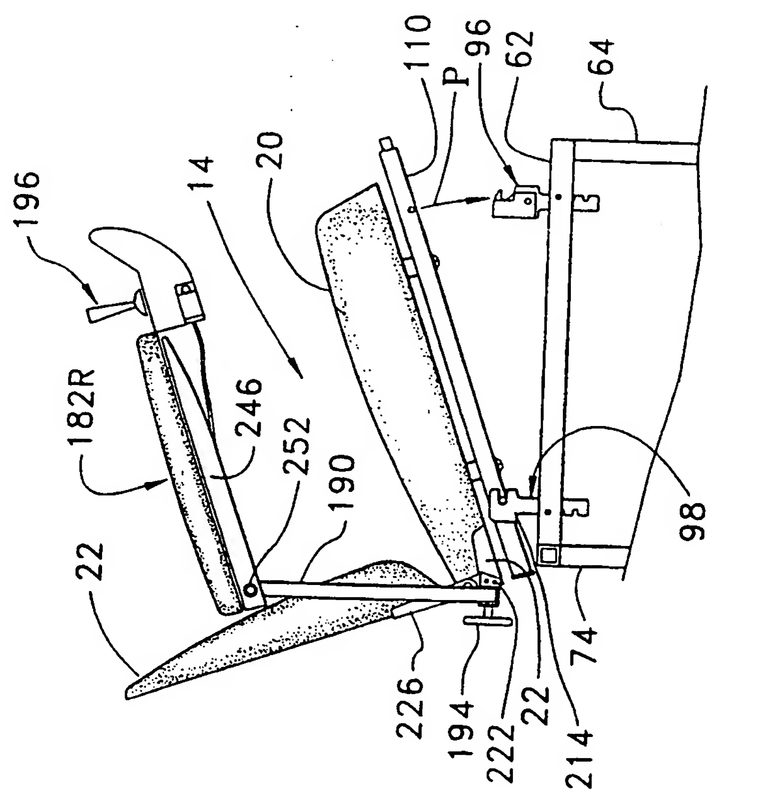
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FIG. Z

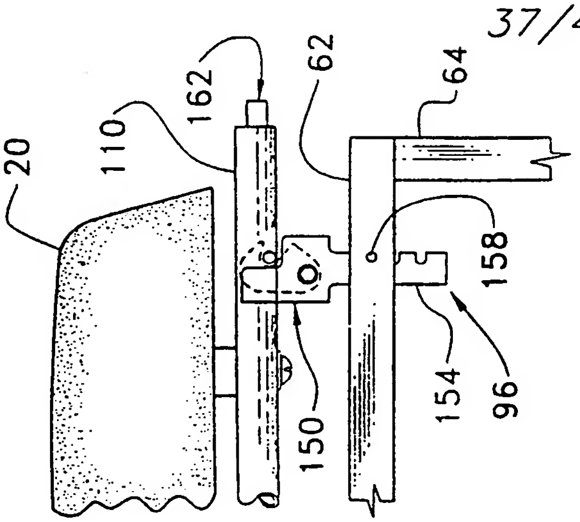

FIG. CC

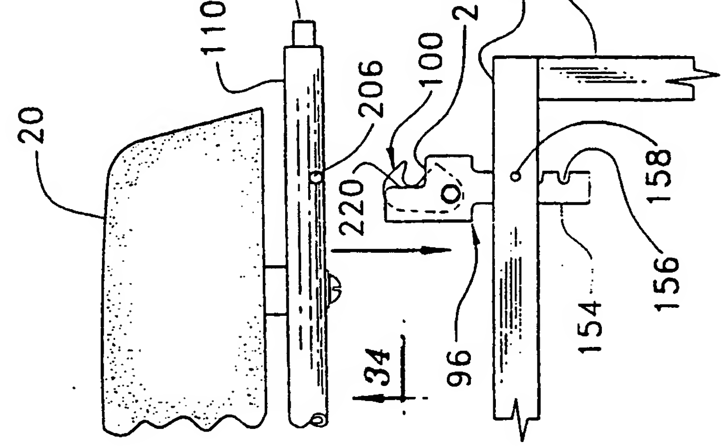

FIG. DD

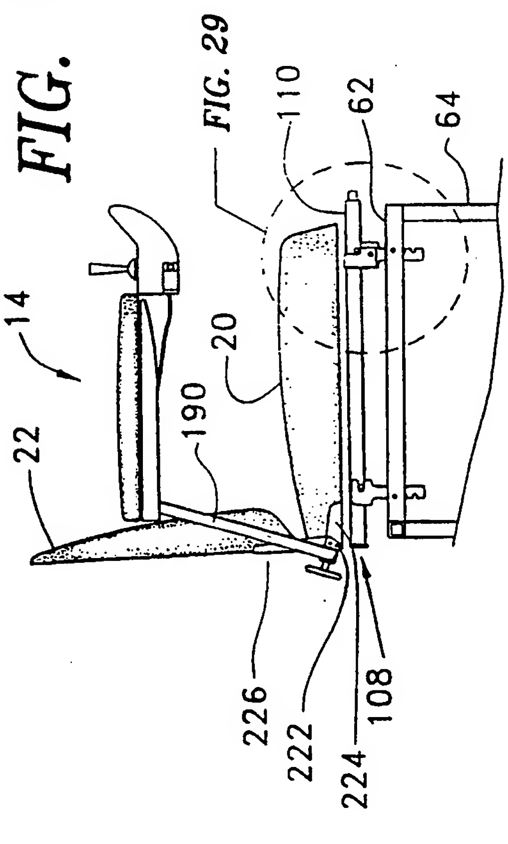

FIG. Y

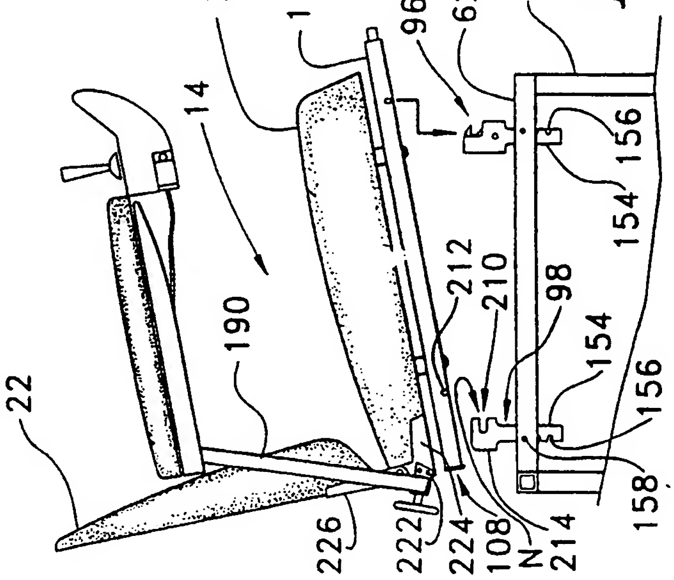

FIG. BB

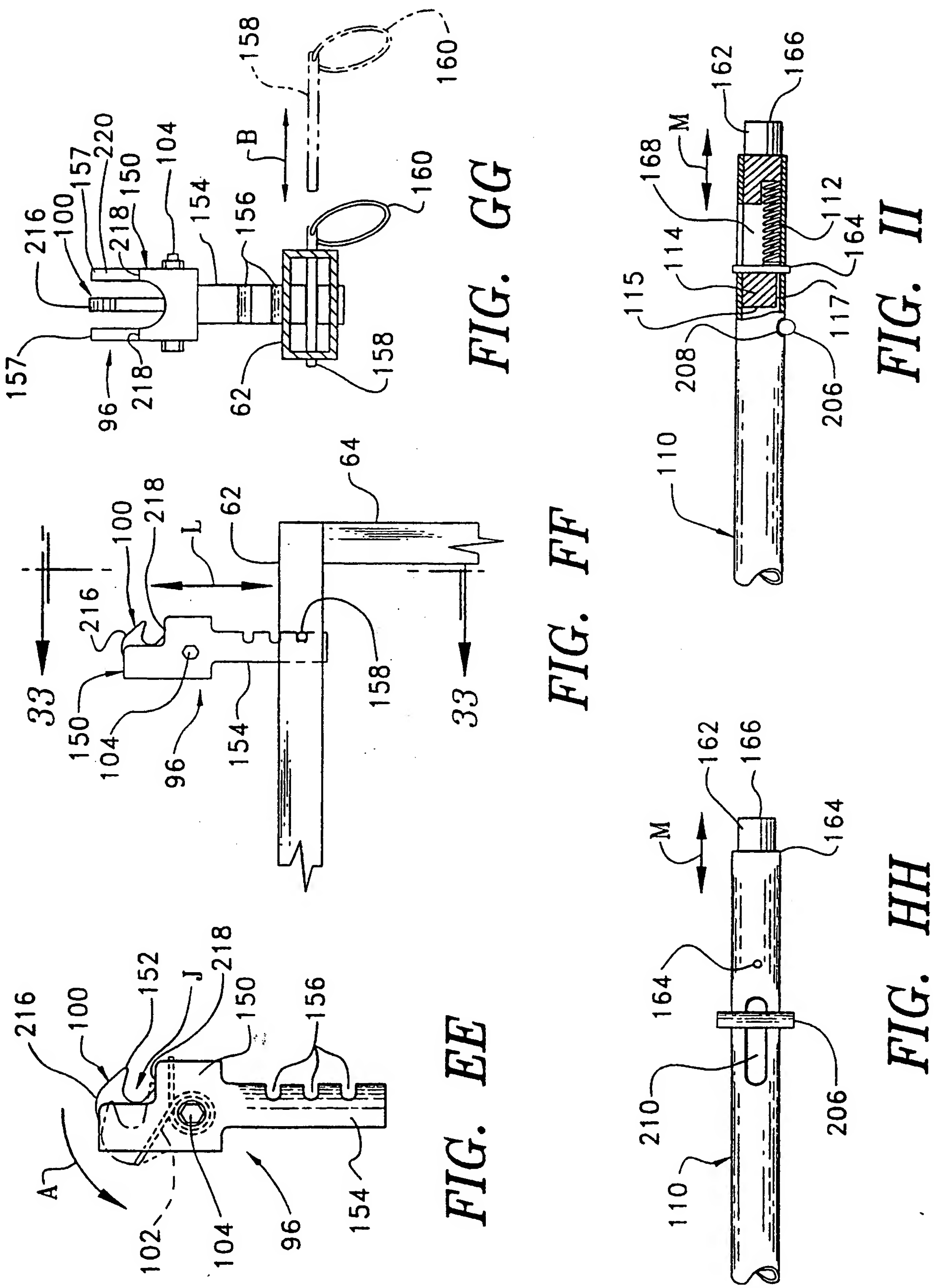

FIG. GG

FIG. FF

FIG. EE

FIG. II

FIG. HH

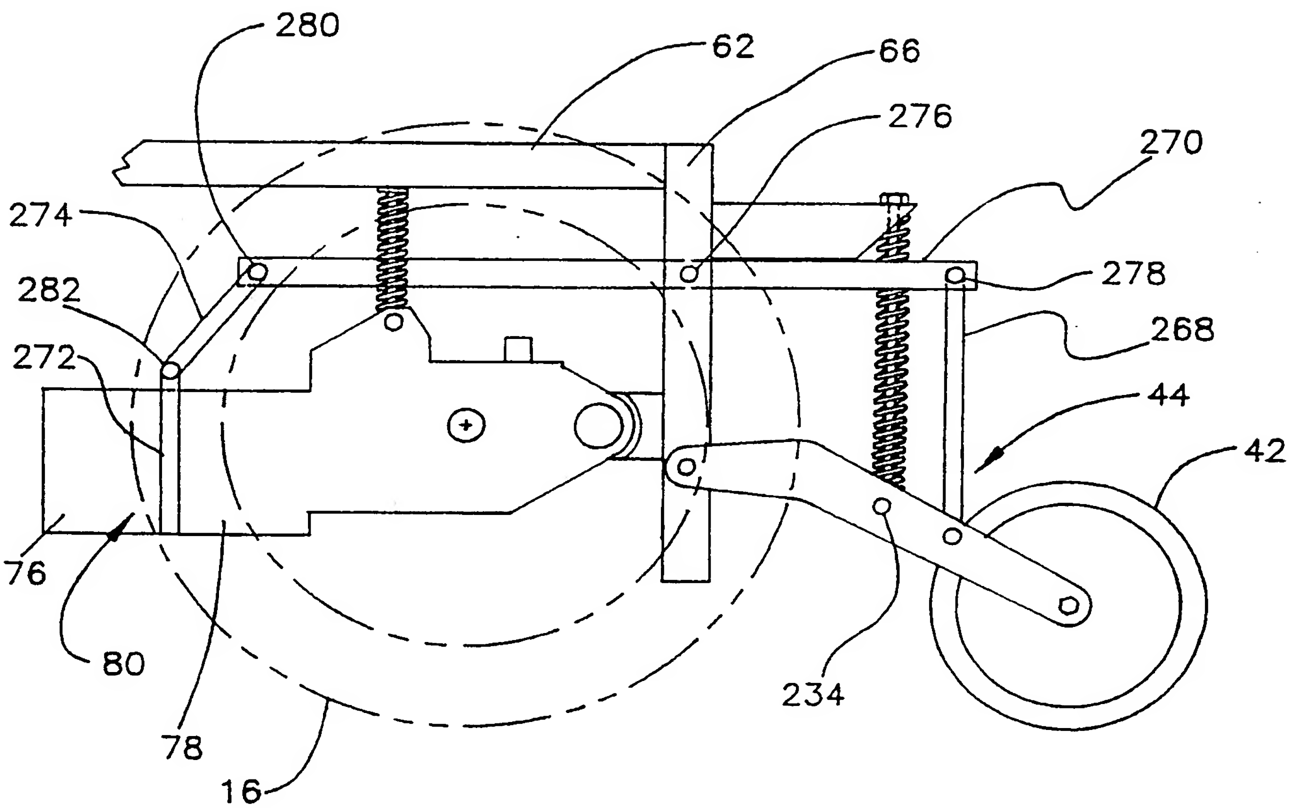

FIG. MM

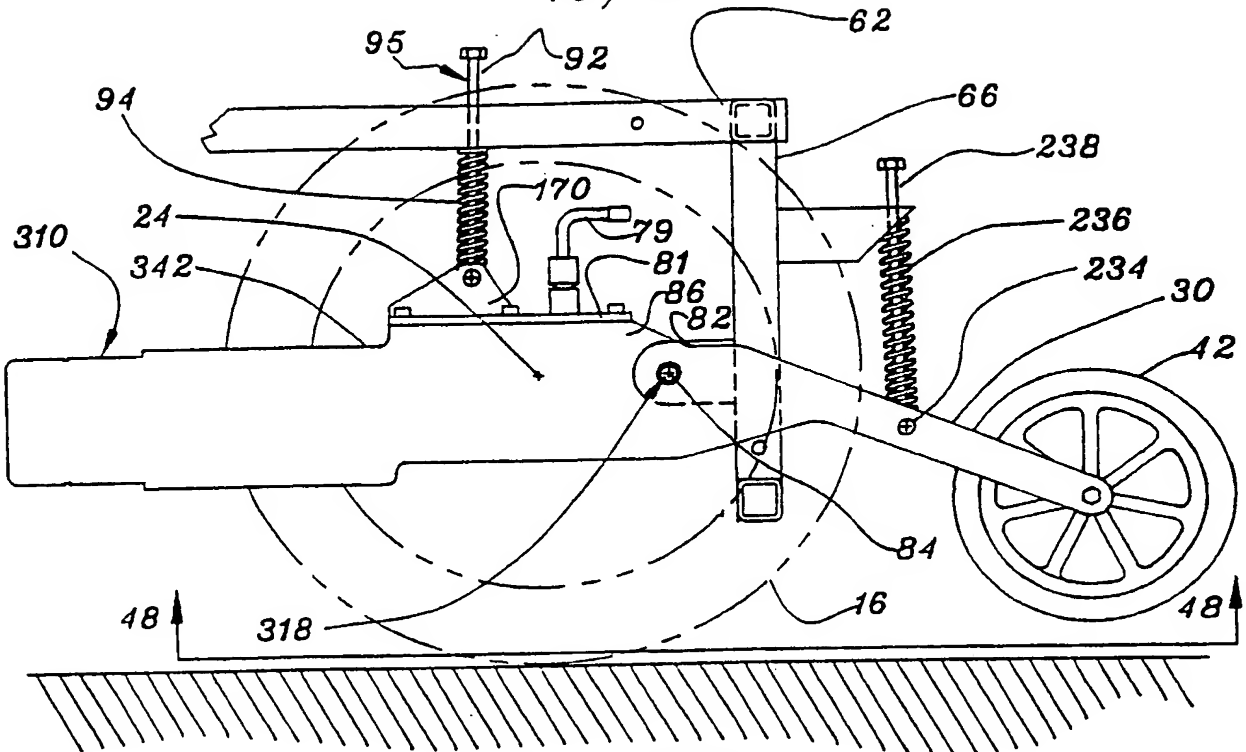
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Fig. NN

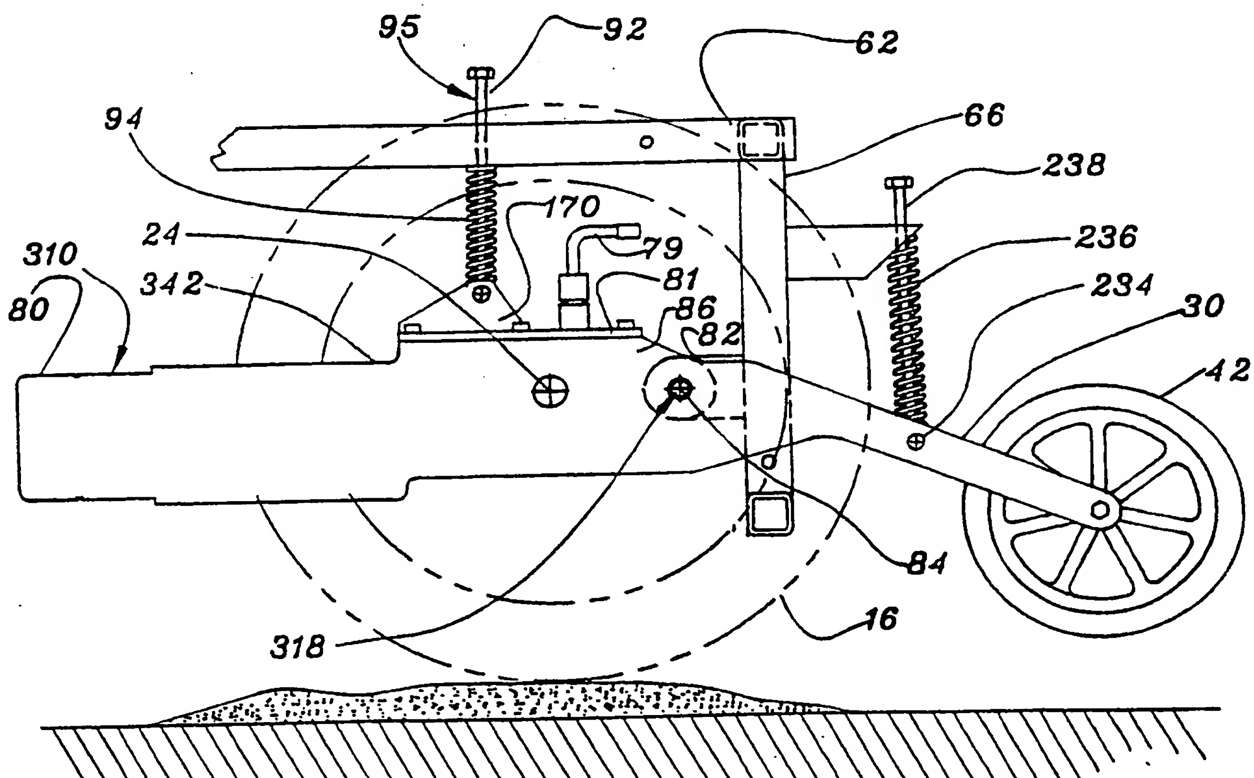
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Fig. OO

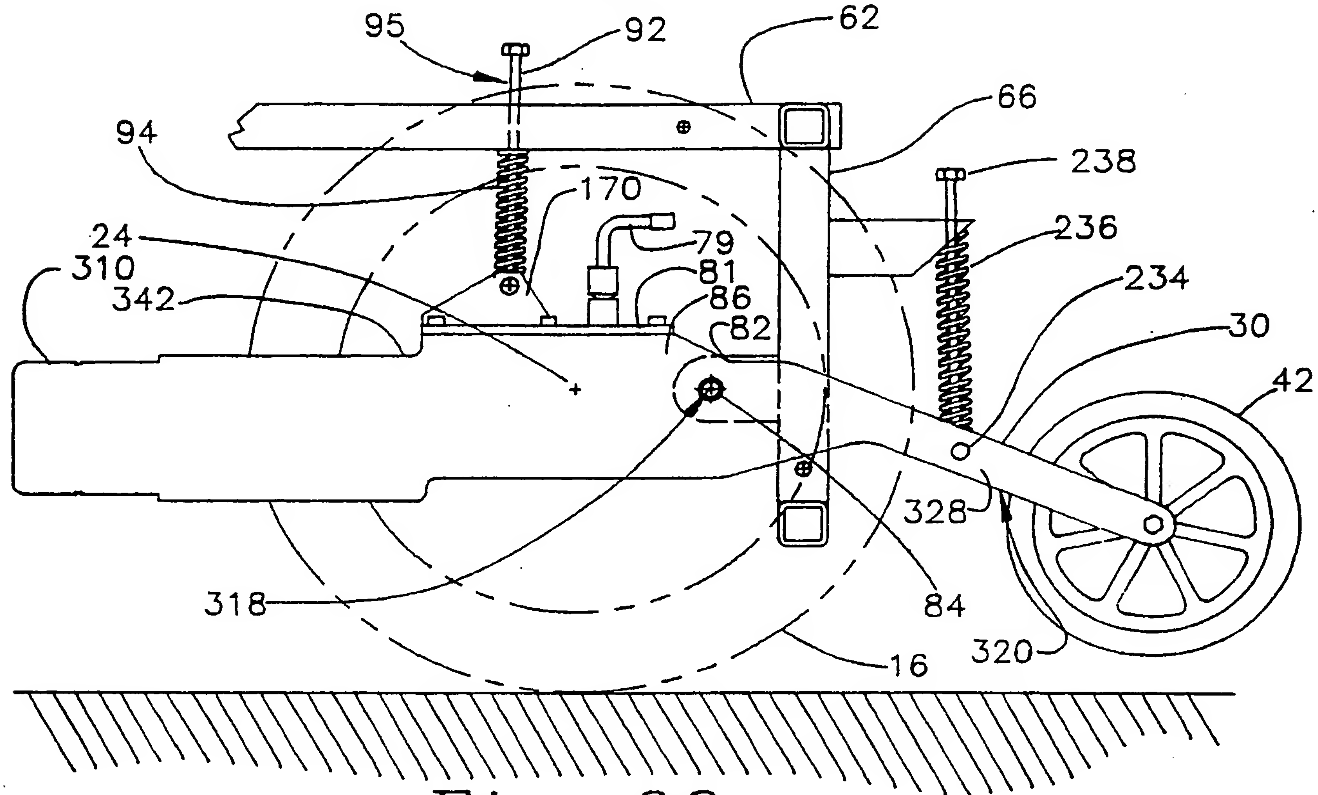
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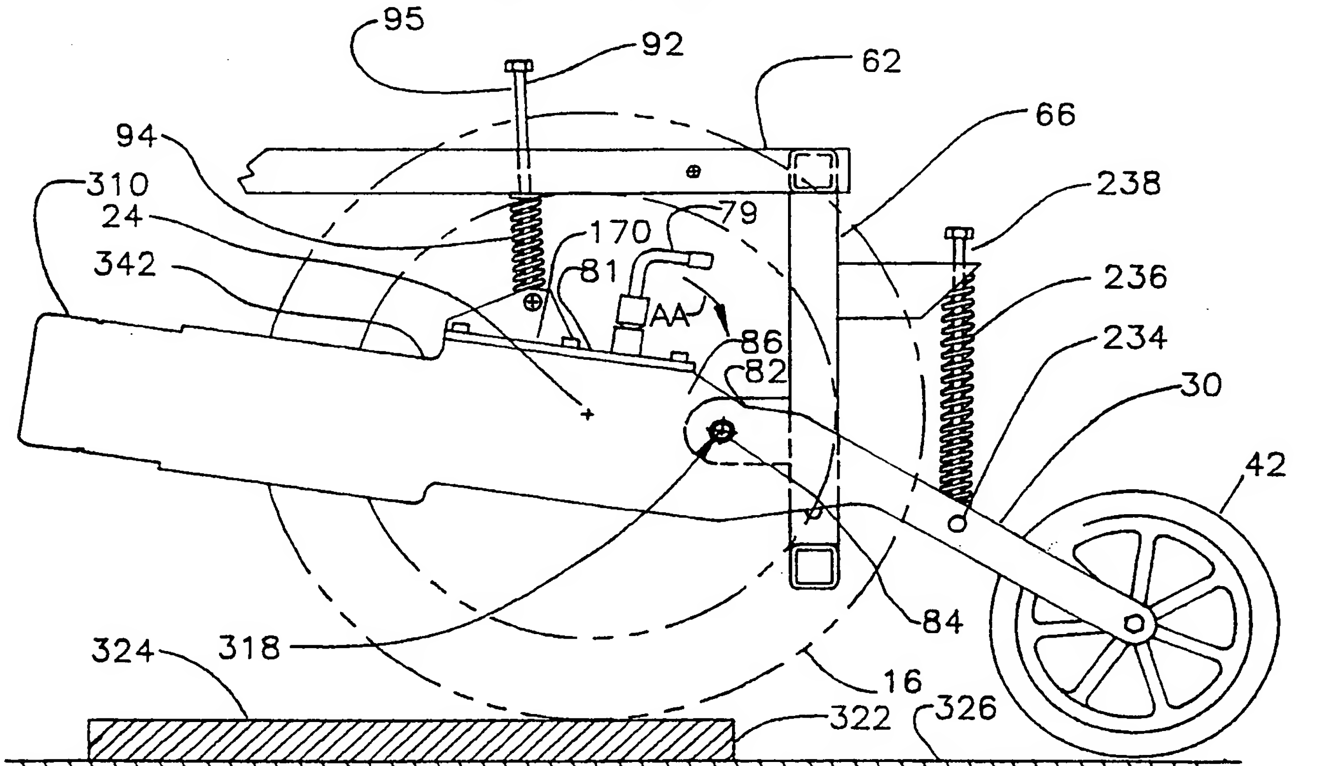
Fig. QQ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Fia. PP

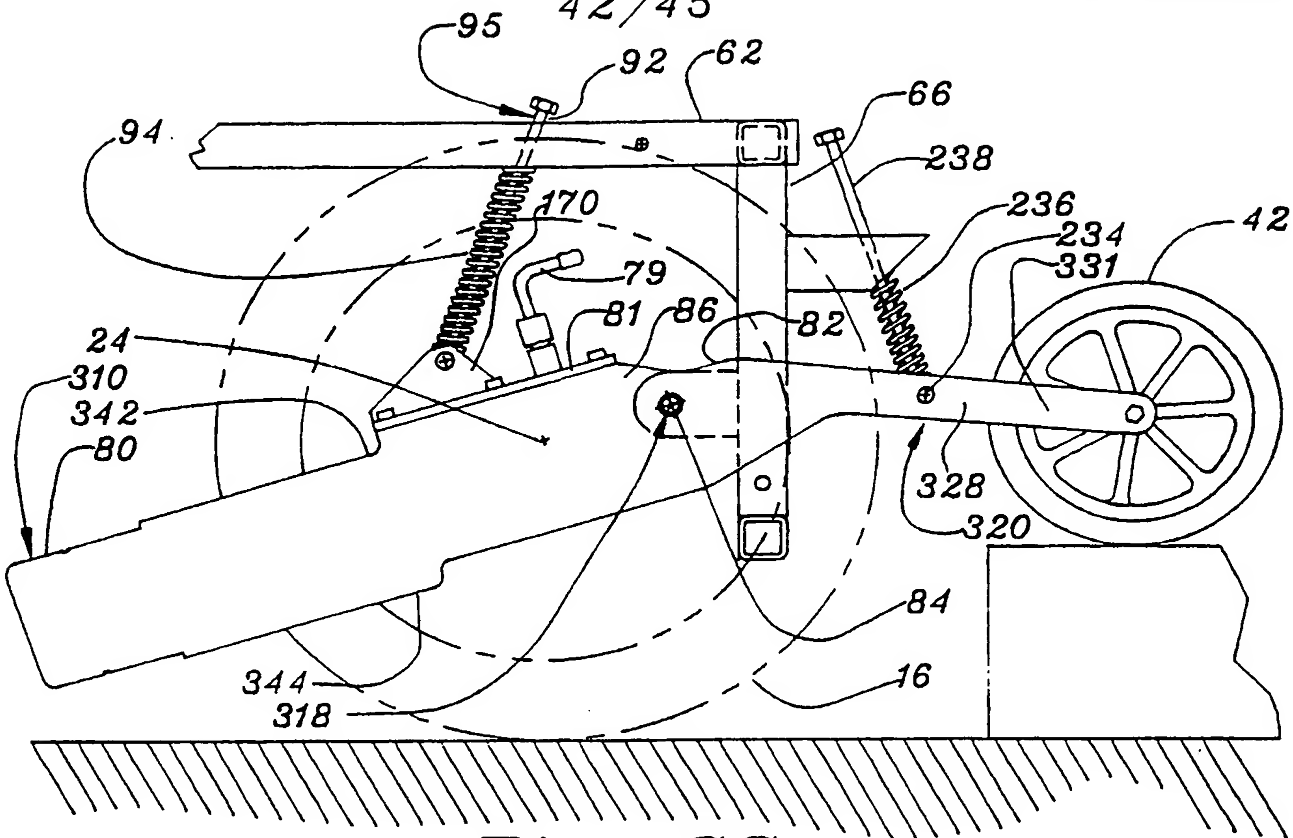
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Fig. SS

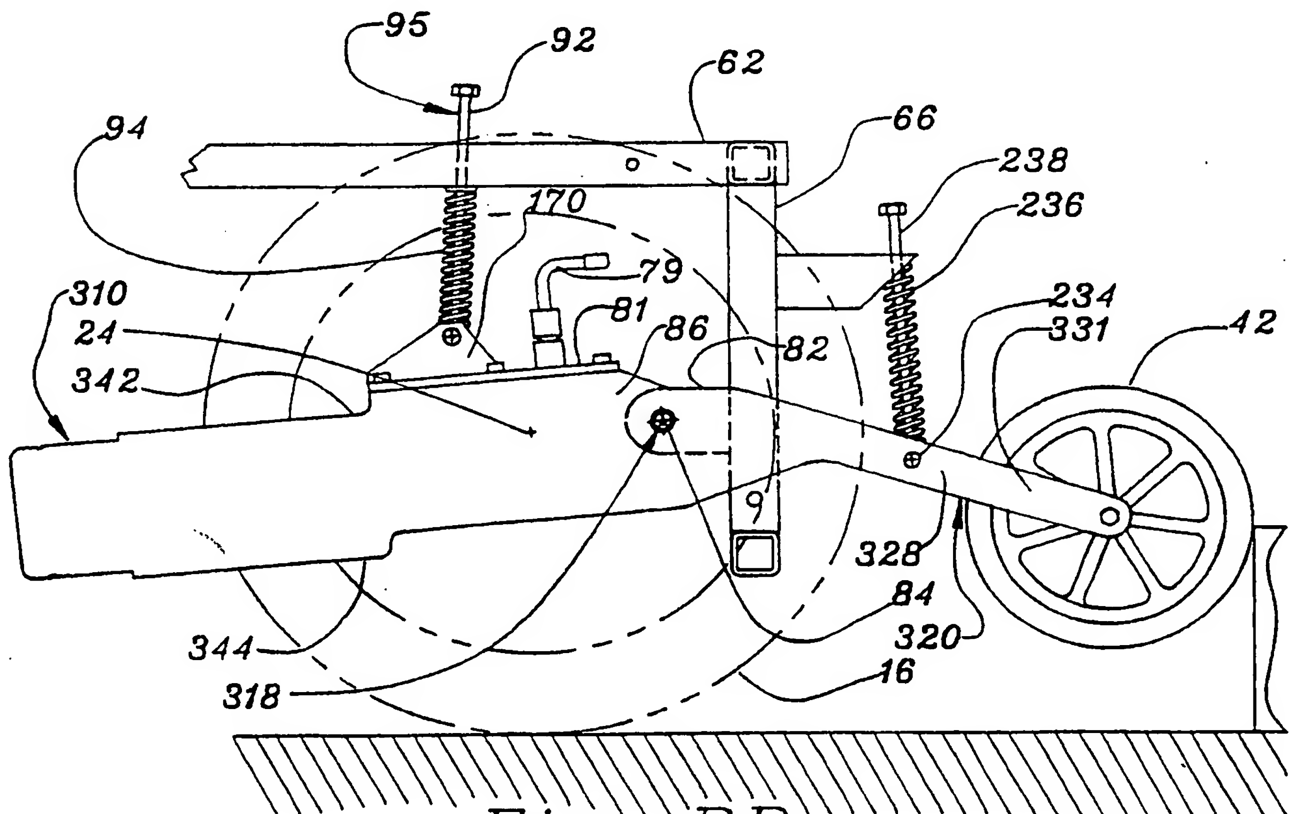
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Fig. RR

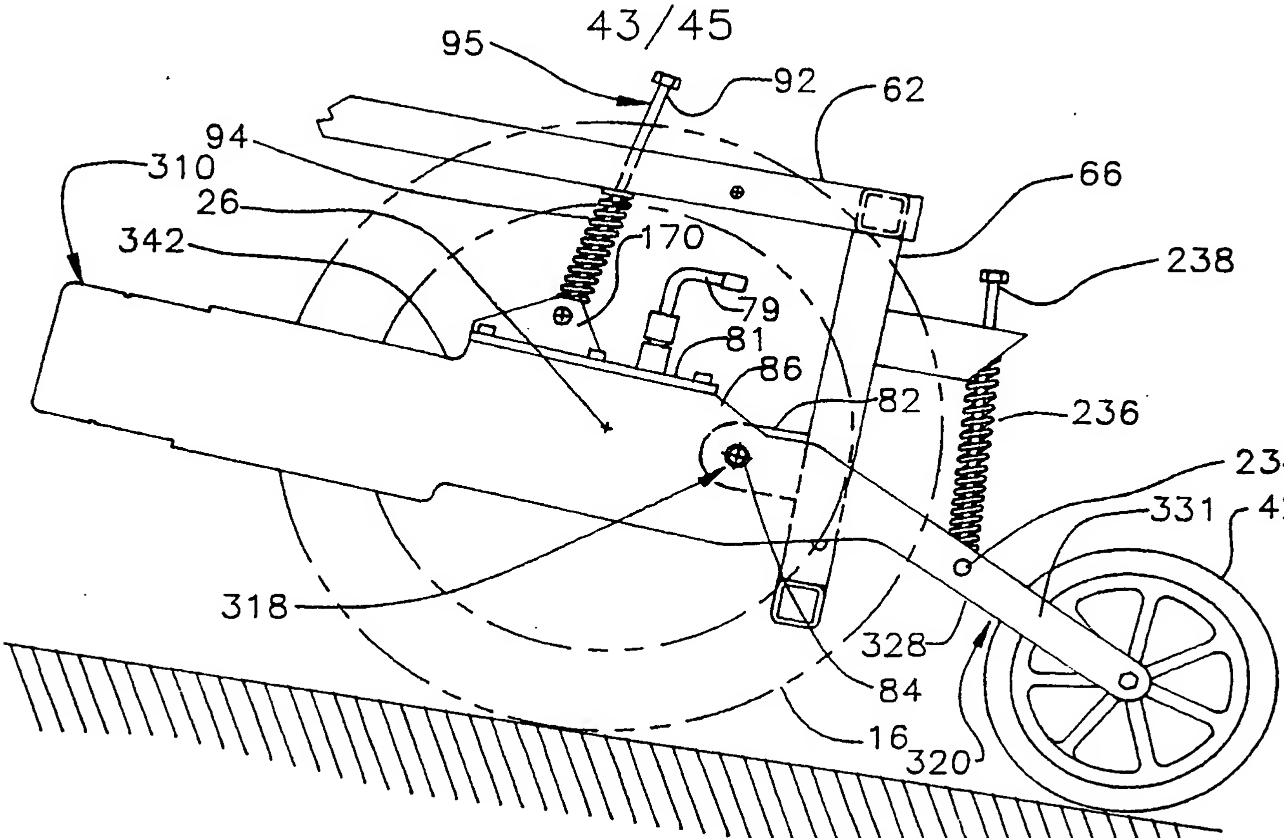
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Fig. TT

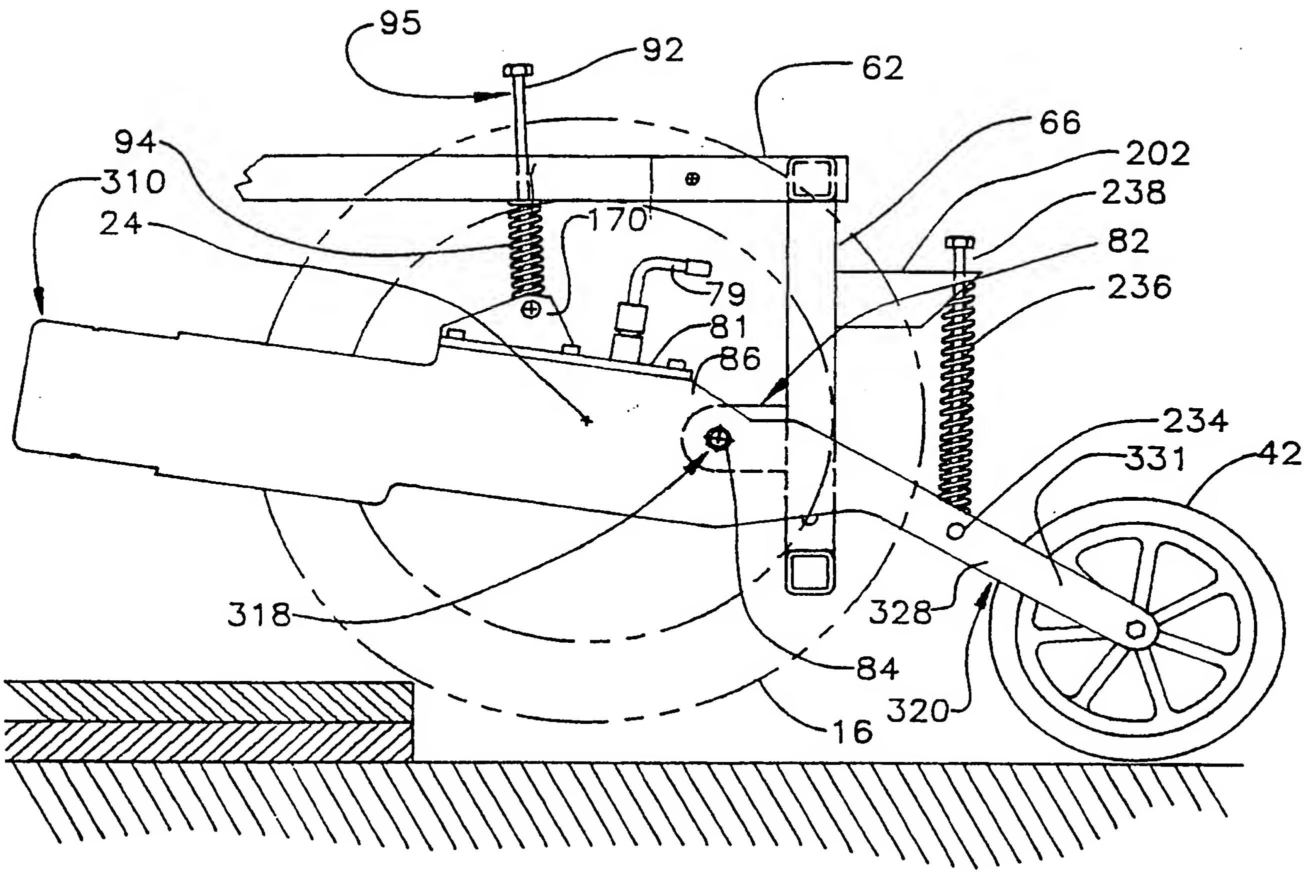
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Fig. UU

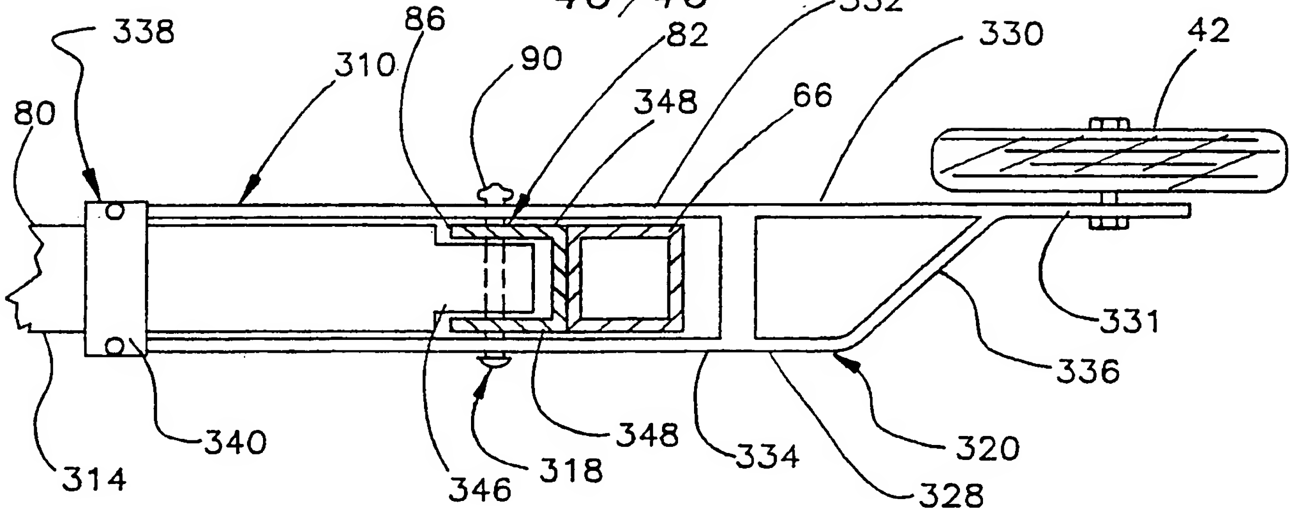

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Fig. VV

INTERNATIONAL SEARCH REPORT

Inter   ›nal Application No
PCT/US 98/20903

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A61G5/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 A61G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	FR 2 399 822 A (DUPONT LIT SA) 9 March 1979 see the whole document	1,4,7
Y	US 4 431 076 A (SIMPSON ROBERT C) 14 February 1984 see the whole document	1,4,7
A	WO 96 15752 A (DEGONDA ANDRE ;DEGONDA REHAB SA (CH); WUETHRICH THOMAS (CH)) 30 May 1996 see page 16, line 19 - line 27 see page 17, line 5 - line 14; figures 13,15	1-3, 11-13,18

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
8 February 1999	16/02/1999

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INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/US 98/20903

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 513 832 A (ENGMAN BO H S) 30 April 1985 cited in the application see the whole document -----	1,11,18

1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

.formation on patent family members

Inter· ›nal Application No
PCT/US 98/20903

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
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US 4431076	A	14-02-1984	NONE			
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			AU	3837895	A	17-06-1996
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			SE	8202763	A	04-11-1983

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(51) International Patent Classification 6 : A61G 5/04	A1	(11) International Publication Number: **WO 99/17701** (43) International Publication Date: 15 April 1999 (15.04.99)

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(30) Priority Data:
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(74) Agent: QUINN, Charles, N.; Dann, Dorfman, Herrell & Skillman, Suite 720, 1601 Market Street, Philadelphia, PA 19103-2307 (US).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

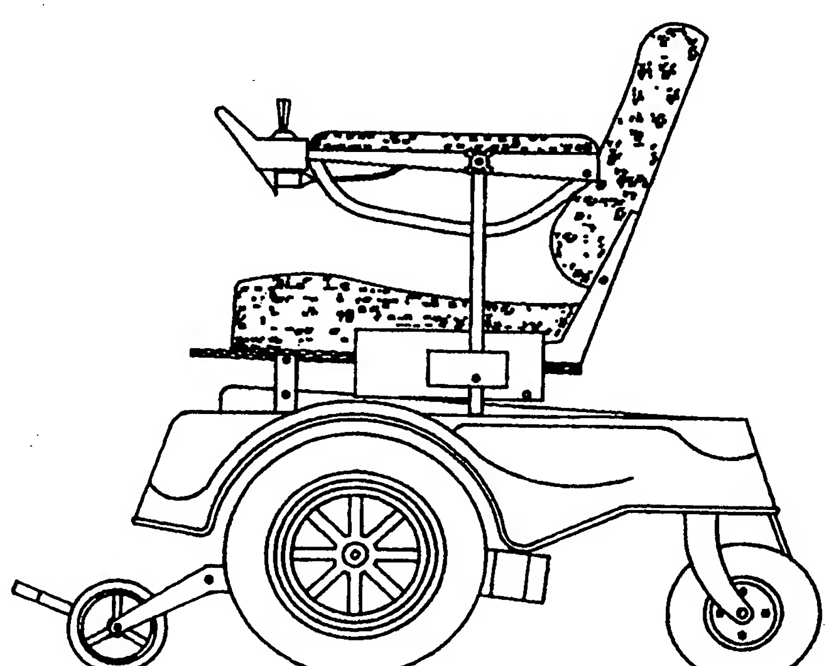
Published
With international search report.
With amended claims and statement.

Date of publication of the amended claims and statement: 24 June 1999 (24.06.99)

(54) Title: FOLDABLE POWER WHEELCHAIR

(57) Abstract

A power chair comprising: a frame transversely foldable between operating and transport positions, a seat connected to said frame, a pair of drive wheels connected to said frame and rotatable about transverse axes below a portion of said seat supporting an occupant's thighs, motors for driving respective drive wheels, respective motor/drive wheel combinations being pivotally connected to said frame, one ground-engaging idler wheel connected to said frame and located rearward of said drive wheels and one anti-tip wheel forward of said drive wheels and positioned above ground, connected to said frame for movement relative to said frame upon encountering an obstacle.



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AMENDED CLAIMS

[received by the International Bureau on 15 April 1999 (15.04.99); original claims 1-7 and 11-18 amended; new claims 19-21 added; remaining claims unchanged (8 pages)]

1. A power chair comprising:
   a. a frame transversely foldable between operating and transport positions;
   b. a seat removably fixable to said frame when said frame is in said operating position;
   c. a pair of drive wheels connected to said frame and rotatable about transverse axes below a portion of said seat supporting an occupant's thighs;
   d. motors for driving respective drive wheels, respective motor/drive wheel combinations being pivotally connected to said frame;
   e. at least one ground-engaging idler wheel pivotally connected to said frame for rotary movement about vertical and longitudinal axes located rearwardly of said drive wheels; and
   f. at least one anti-tip wheel forward of said drive wheels and positioned above ground when said drive wheels and said idler where contact level ground and said frame is in said operating position, connected to said frame for movement relative to said frame and away from said drive wheels upon encountering an obstacle.

2. The power chair of claim 1 further comprising spring-strut assemblies connecting said anti-tip wheels to said frame for resiliently resisting upward movement of said anti-tip wheels away from said frame upon encountering an obstacle.

3. The power chair of claim 2 wherein said spring-strut assemblies further comprise:
   a. a strut connected to said anti-tip wheel and moveable upwardly therewith;
   b. a spring coiled about said strut;
   c. means connected to said frame for constraining an

upper end of said spring against upward movement while permitting slidable upward passage of said strut therethrough including a sleeve slidably receiving said strut and fitting within the interior of said spring and a cap portion connecting with an upper portion of said sleeve, having a rounded exterior upper surface facilitating relative rotary motion of said constraining means respecting said frame responsively to an associated anti-tip wheel upwardly displacing said strut and compressing said spring upon encountering an obstacle.

4. The power chair of claim 1 wherein said frame has a pair of rigid parallel longitudinally elongated side members pivotally connected by a plurality of pivotally connected transversely elongated cross member links adapted for arcuate movement about longitudinal axes.

5. The power chair of claim 4 wherein said cross members lines are transverse to said side members and said pivotal connections of said links and said side members prevent link rotation about longitudinal axes.

6. The power chair of claim 1 wherein said seat further comprises a pair of transversely spaced arms positioned on respective sides of said and said power chair further comprises means connected to said frame for adjustably positioning said arms at a plurality of heights, comprising:
   a. a tongue fixedly connected to said arm, having a plurality of recesses in the surface thereof;
   b. a housing connected to said frame and having a movable portion with a receptacle of varying depth formed therein, said portion being movable among positions at which various regions of said receptacle having

differing depth communicate with a selected one of said recesses; and

c. means resident in said receptacle of size for fitting into said selected recess with which said receptacle is communicating for interfering with movement of said tongue relative to said housing when said movable means is in a relatively shallow depth portion of said receptacle and freely permitting movement of said tongue when said movable means is in a relatively deep depth portion of said receptacle.

7. The power chair of claim 1 further comprising:

a. manually actuable stick means for controlling speed and direction of power chair motion; and

b. substantially horizontal four bar parallelogram-configured linkage means supportingly connecting said control stick means to said frame for permitting rotational horizontal angle movement thereof between at least two positions while maintaining said stick means in a fixed orientation relative to a vertical axis of said power chair.

8. The power chair of claim 1 wherein said seat includes a generally horizontal occupant vertical support portion and said power chair further comprises:

a. an occupant transfer board pivotally connected to said frame and movable between positions generally parallel and skew respecting said occupant vertical support portion.

9. The power chair of claim 8 wherein said parallel position is co-planar with said occupant vertical support portion and said skew position is generally perpendicular to said occupant vertical support portion.

10. The power chair of claim 9 further comprising:
   a. resilient means for biasing said transfer board towards one of said parallel and skew positions; and
   b. detent means for retaining said transfer board at a selected position intermediate said parallel and skew positions in opposition to said resilient means.

11. A power chair comprising:
   a. a frame transversely foldable between operating and transport positions;
   b. a seat removably fixable to said frame when said frame is in said operating position;
   c. a pair of drive wheels connected to said frame and rotatable about transverse axes below a portion of said seat supporting an occupant's thighs;
   d. motors for driving respective drive wheels, respective motor/drive wheel combinations being pivotally connected to said frame;
   e. at least one ground-engaging idler wheel pivotally connected to said frame for rotary movement about vertical and longitudinal axes located rearwardly of said drive wheels; and
   f. a pair of anti-tip wheels forward of said drive wheels and positioned above ground, connected to respective ones of said motors for pivotal movement unitarily therewith relative to said frame responsively to changes in drive wheel velocity.

12. The power chair of claim 11 further comprising spring-strut assemblies connecting said anti-tip wheels to said frame for resiliently resisting upward movement of said anti-tip wheels away from said frame upon encountering an obstacle.

13. The power chair of claim 12 wherein said spring-strut assemblies further comprise:

a. a strut connected to said anti-tip wheel and moveable upwardly therewith;

b. a spring coiled about said strut;

c. means connected to said frame for constraining an upper end of said spring against upward movement while permitting slidable upward passage of said strut therethrough including a sleeve slidably receiving said strut and fitting within the interior of said spring and a cap portion connecting with an upper portion of said sleeve, having a rounded exterior upper surface facilitating relative rotary motion of said constraining means respecting said frame responsively to an associated anti-tip wheel upwardly displacing said strut and compressing said spring upon encountering an obstacle.

14. The power chair of claim 12 wherein said frame has a pair of rigid parallel longitudinally elongated side members pivotally connected by a plurality of pivotally connected transversely elongated cross member links adapted for arcuate movement about longitudinal axes.

15. The power chair of claim 14 wherein said cross members lines are transverse to said side members and said pivotal connections of said links and said side members prevent link rotation about longitudinal axes.

16. The power chair of claim 15 wherein said seat further comprises a pair of transversely spaced arms positioned on respective sides of said and said power chair further comprises means connected to said frame for adjustably positioning said arms at a plurality of heights, comprising:

a. a tongue fixedly connected to said arm, having a plurality of recesses in the surface thereof;

b. a housing connected to said frame and having a movable portion with a receptacle of varying depth formed therein, said portion being movable among positions at which various regions of said receptacle having differing depth communicate with a selected one of said recesses; and

c. means resident in said receptacle of size for fitting into said selected recess with which said receptacle is communicating for interfering with movement of said tongue relative to said housing when said movable means is in a relatively shallow depth portion of said receptacle and freely permitting movement of said tongue when said movable means is in a relatively deep depth portion of said receptacle.

17. The power chair of claim 11 further comprising:

a. manually actuable stick means for controlling speed and direction of power chair motion; and

b. substantially horizontal four bar parallelogram-configured linkage means supportingly connecting said control stick means to said frame for permitting rotational horizontal angle movement thereof between at least two positions while maintaining said stick means in a fixed orientation relative to a vertical axis of said power chair.

18. A power chair comprising:

a. a frame transversely foldable between operating and transport positions;

b. a seat removably fixable to said frame when said frame is in said operating position;

c. a pair of drive wheels connected to said frame and rotatable about transverse axes below a portion of said seat supporting an occupant's thighs;

d. motors for driving respective drive wheels, respective

motor/drive wheel combinations being pivotally connected to said frame;

e. at least one ground-engaging idler wheel pivotally connected to said frame for rotary movement about vertical and longitudinal axes located rearwardly of said drive wheels;

f. at least one anti-tip wheel forward of said drive wheels and positioned above ground when said drive wheels and said idler where contact level ground and said frame is in said operating position, connected to said frame for movement relative to said frame and away from said drive wheels upon encountering an obstacle;

g. a strut connected to said anti-tip wheel and moveable upwardly therewith;

h. a spring coiled about said strut;

i. means connected to said frame for constraining an upper end of said spring against upward movement while permitting slidable upward passage of said strut therethrough including a sleeve slidably receiving said strut and fitting within the interior of said spring and a cap portion connecting with an upper portion of said sleeve, having a rounded exterior upper surface facilitating relative rotary motion of said constraining means respecting said frame responsively to an associated anti-tip wheel upwardly displacing said strut and compressing said spring upon encountering an obstacle; wherein said frame has a pair of rigid parallel side members connected by a plurality of cross members each comprising a plurality of pivotally connected links; wherein said cross members are transverse to said side members and said pivotal connections rotate about longitudinal axes.

19. The power chair of claim 5 wherein said pivotally connected links further comprise a plurality of virtually separated transversely elongated cross member links coupled together for arcuate movement about longitudinal axes.

20. The power chair of claim 4 wherein said pivotally connected links further comprise a plurality of virtually separated transversely elongated cross member links coupled together for arcuate movement about longitudinal axes.

21. The power chair of claim 11 wherein said pivotally connected links further comprise a plurality of virtually separated transversely elongated cross member links coupled together for arcuate movement about longitudinal axes.

STATEMENT UNDER ARTICLE 19

The claims newly submitted for this application seek to emphasize the novel features of the invention by noting that the foldable power chair includes not only a transversely foldable frame but also a seat which is removably fixable to the frame when that frame is in the operating position. The claims further emphasize the novel feature of the invention whereby the power chair includes at least one ground-engaging idler wheel which is pivotally connected to the frame and positioned for rotary movement about vertical and longitudinal axes respecting the frame as the power chair traverses over the ground. The new claims emphasize that the power chair includes at least one anti-tip wheel forward of the drive wheels, positioned above ground

and out of contact with the ground as the drive and idler wheels normally contact the ground, with the anti-tip wheel resiliently connected to the frame for arcuately upward movement relative to the frame and away from the drive wheels upon encountering an obstacle. This geometric configuration with the anti-tip wheels moving arcuately upwardly and away from the drive wheels upon encountering an obstacle provides a power chair which is highly resistive to tipping upon encountering obstacles.

Certain of the new claims further recite that the power chair may include anti-tip wheels positioned forward of the drive wheels and connected to respective ones of the motors driving the drive wheels, for pivotal movement unitarily with the respective motors relative to the frame in response to changes in drive wheel velocity. This arrangement provides a great improvement in curb-climbing and obstacle-climbing capability.